Recent Results from the PandaX-II Experiment

Andi Tan (University of Maryland)
on behalf of the PandaX-II Collaboration
Osaka University, Dec. 21, 2017

PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

International workshop on “Axion physics and dark matter cosmology”

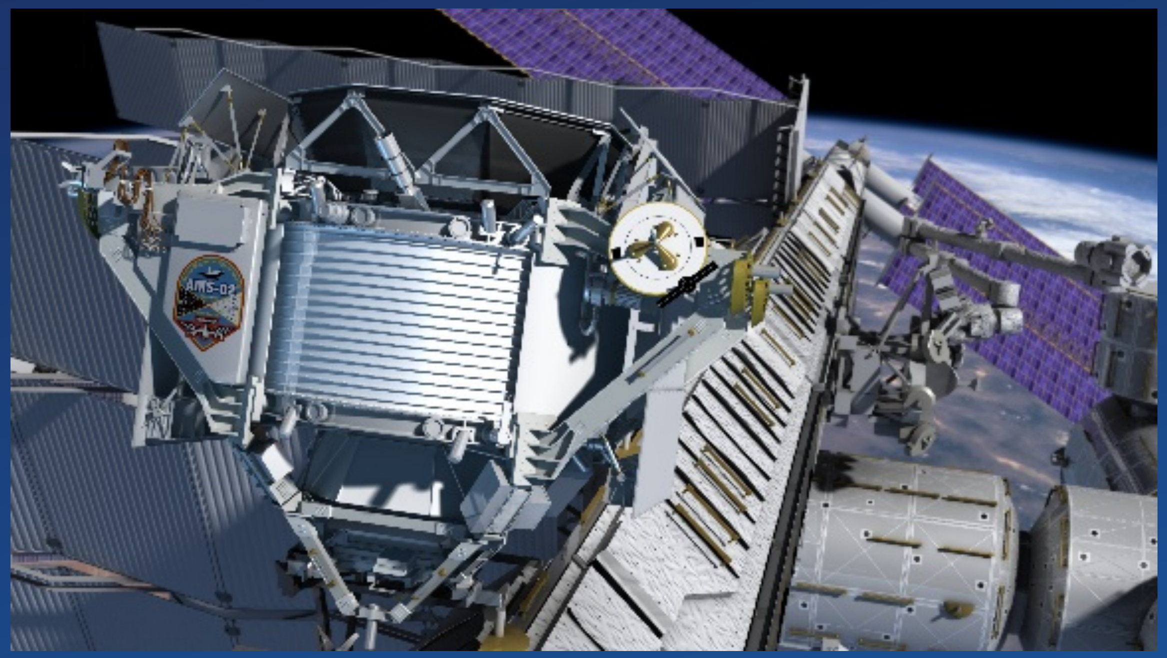
Outline

- Dark Matter Direct Detection
- PandaX at CJPL
- Recent Results from the PandaX-II
- Future of PandaX
- Conclusion

Dark Matter Detection

Indirect Search

AMS



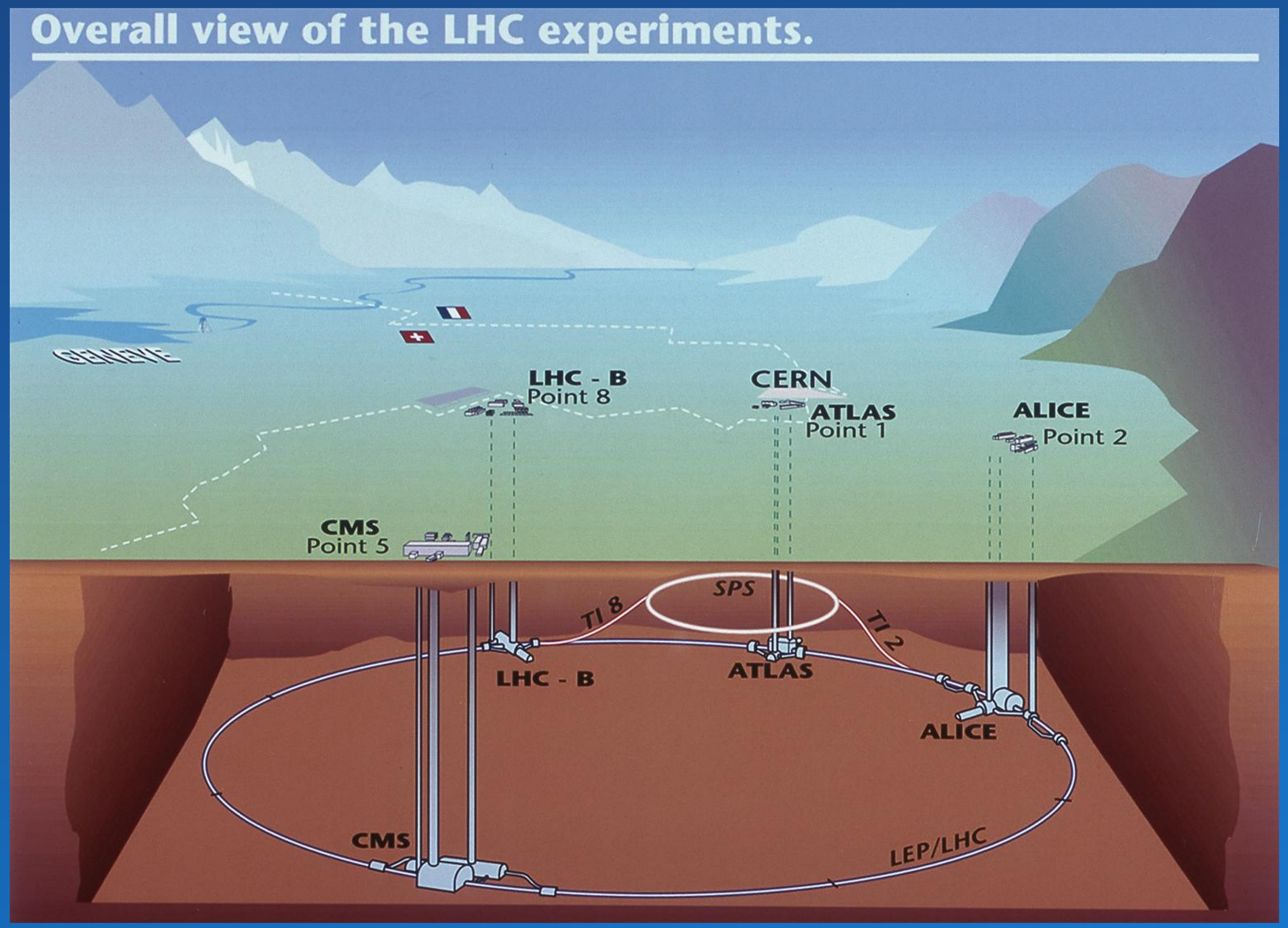
DAMPE

DM DM

?

SM SM

Collider Search



Direct Search

Direct Detection

PHYSICAL REVIEW D VOLUME 31, NUMBER 12 15 JUNE 1985

Detectability of certain dark-matter candidates

Mark W. Goodman and Edward Witten
Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08544
(Received 7 January 1985)

VOLUME 55, NUMBER 1 PHYSICAL REVIEW LETTERS 1 JULY 1985

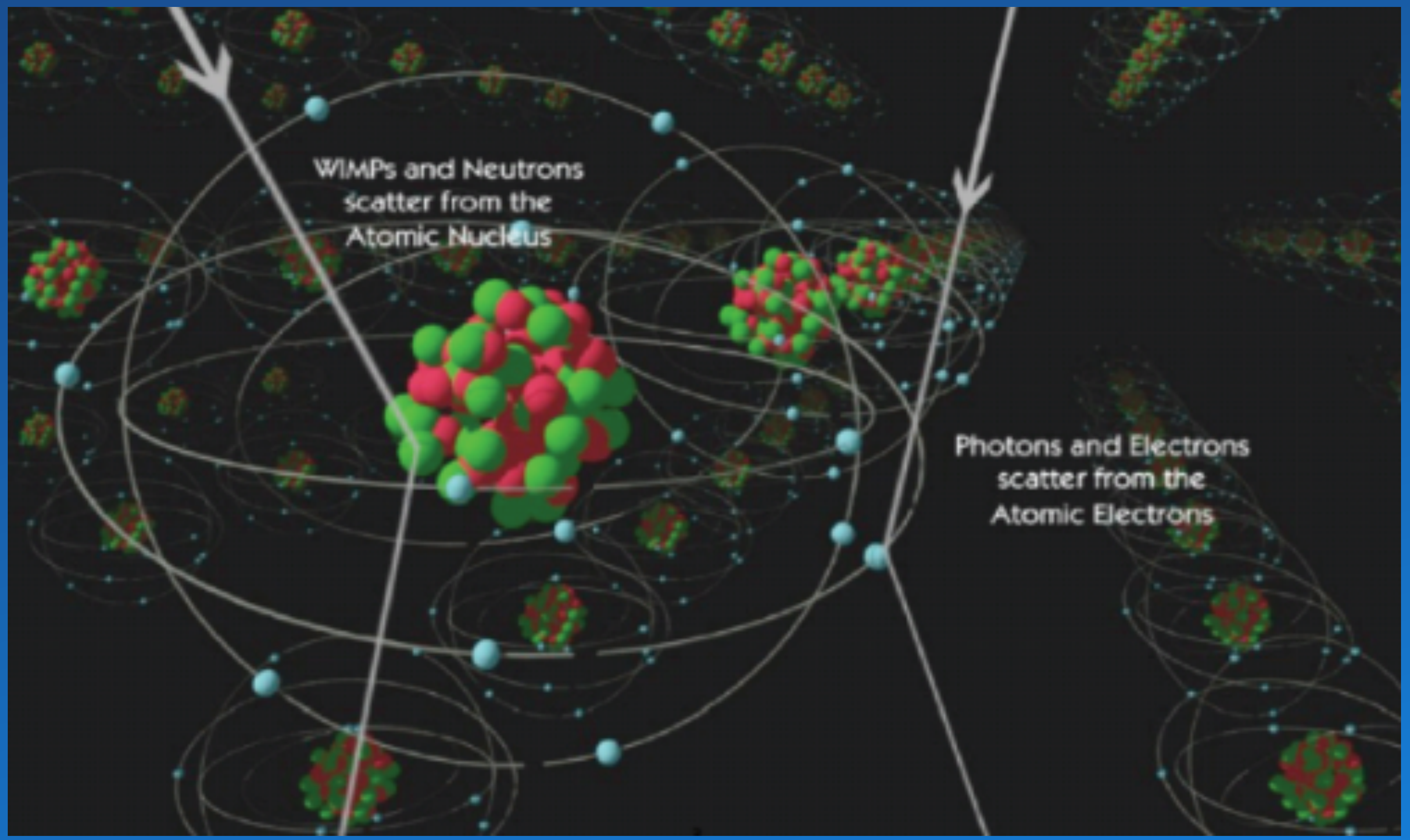
Bolometric Detection of Neutrinos

Blas Cabrera, Lawrence M. Krauss, and Frank Wilczek
Department of Physics, Stanford University, Stanford, California 94305
Lyman Laboratory of Physics, Harvard University, Cambridge, Massachusetts 01238
Institute for Theoretical Physics, University of California, Santa Barbara, California 93106
(Received 14 December 1984)

$$E_1 = \frac{E_0}{(1+A)^2}\left(\cos\theta \pm \sqrt{A^2 - \sin^2\theta}\,\right)^2$$

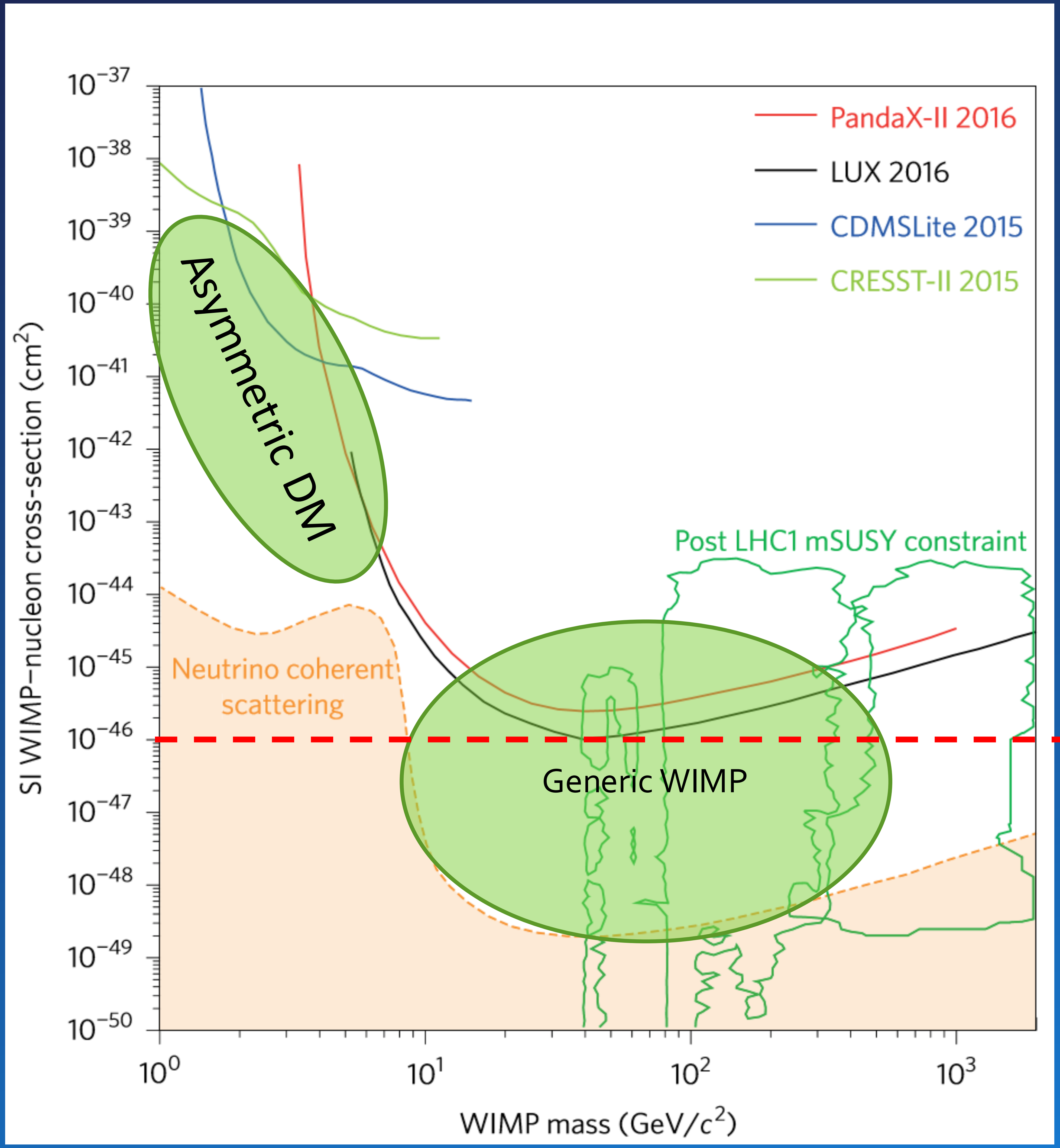
$$T = E_2 = \frac{4A}{(1+A)^2} E_0 \cos^2\phi$$

$A = m_2/m_1$

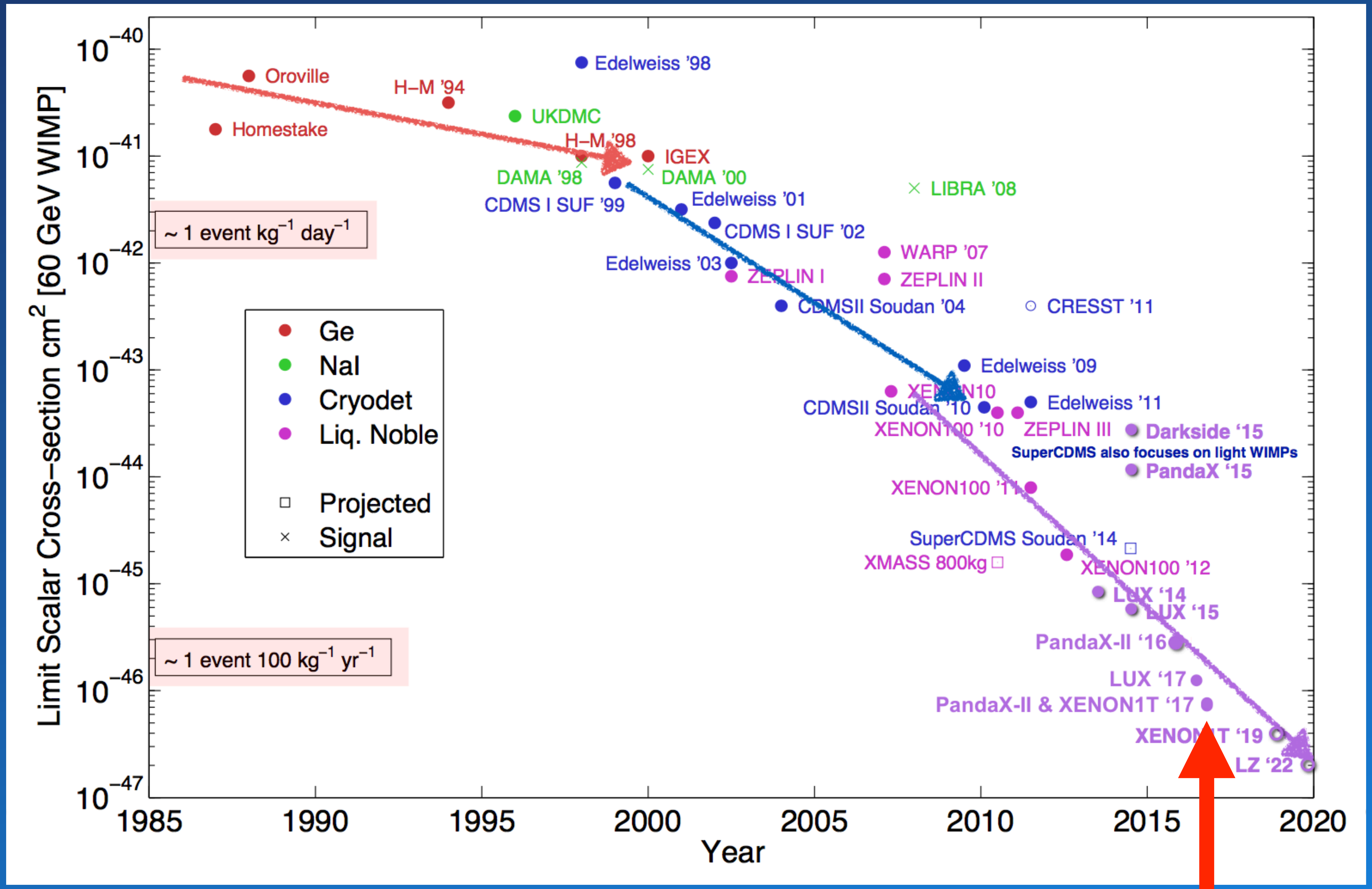


- DM: velocity ~1/1500 c, mass ~100 GeV, KE ~ 20 keV
- Nuclear recoil (NR): recoiling energy ~10 keV
- Electron recoil (ER): 10^{-4} suppression in energy, very difficult to detect
- New ideas exist, e.g. Hochberg, Zhao, and Zurek, PRL 116, 011301

Available Space and Global Racing



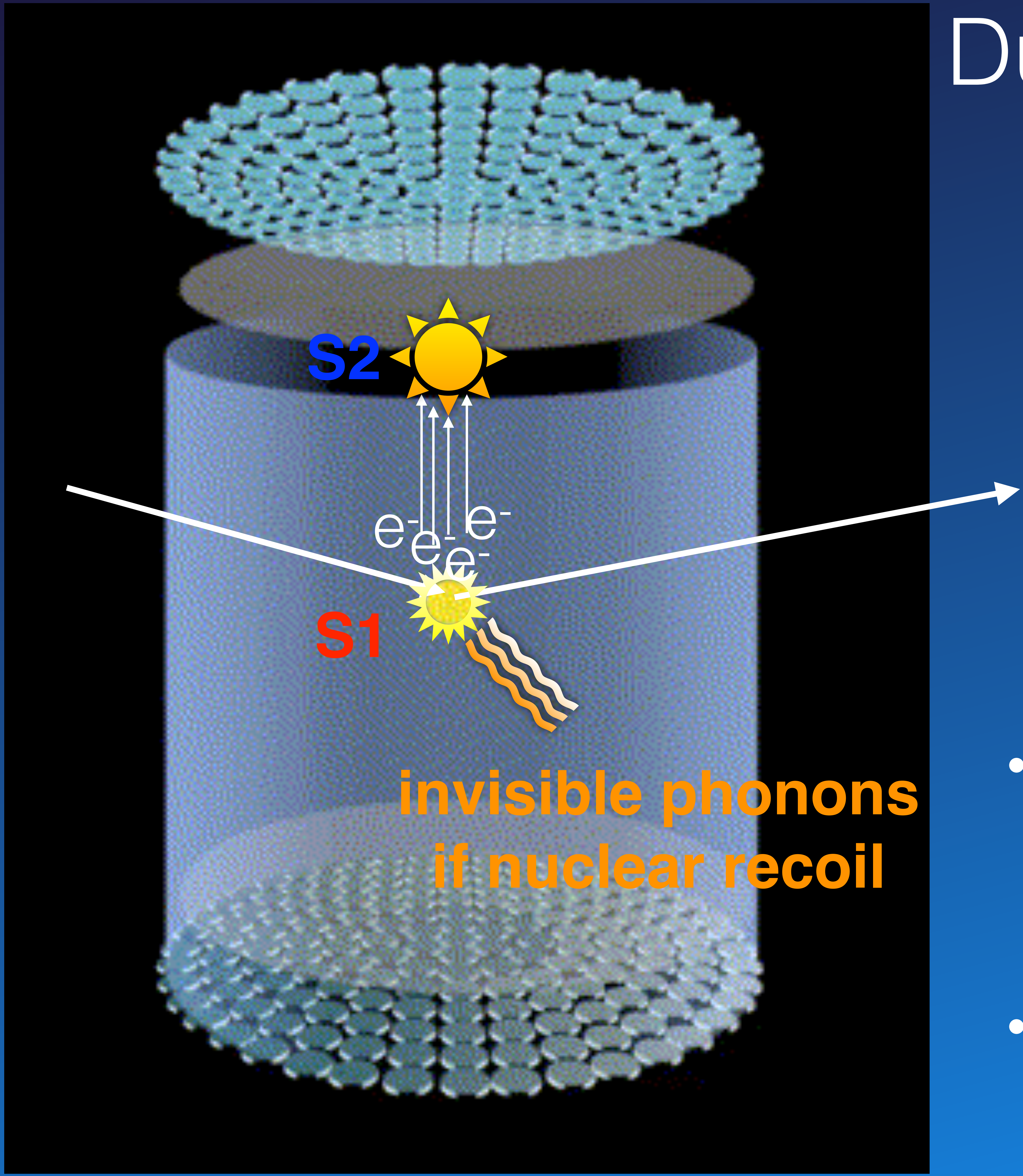
Nature Physics 13, 212–216 (2017)

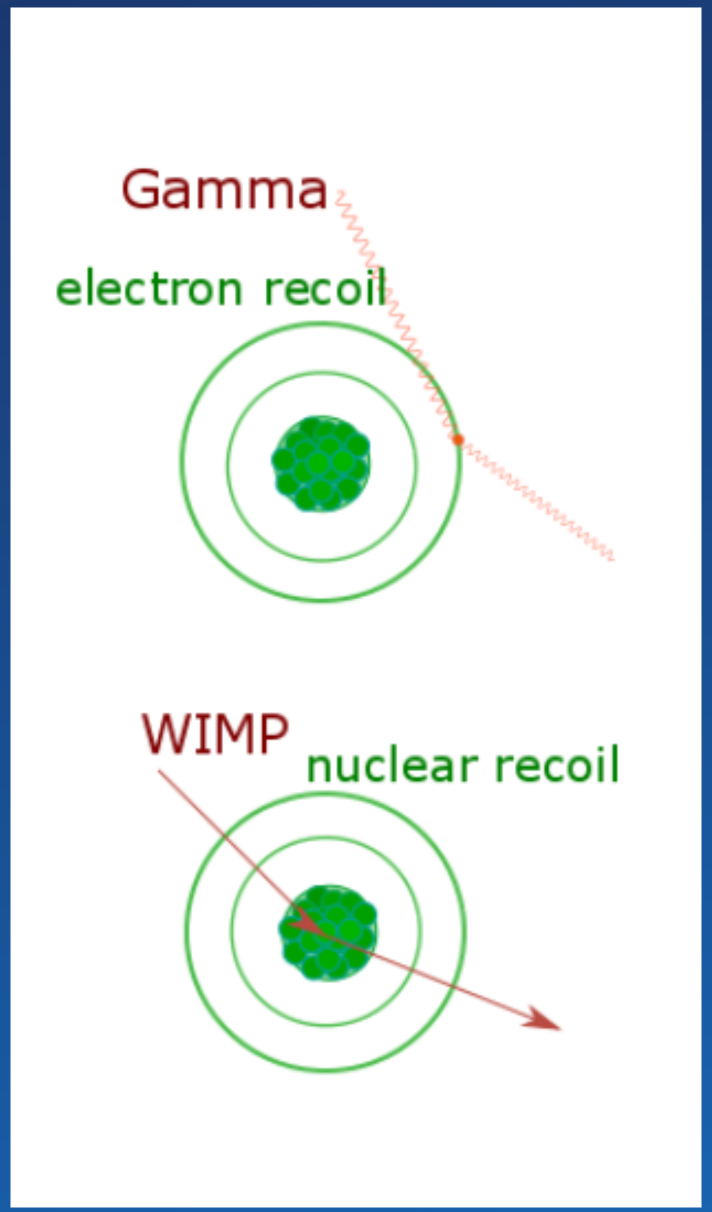


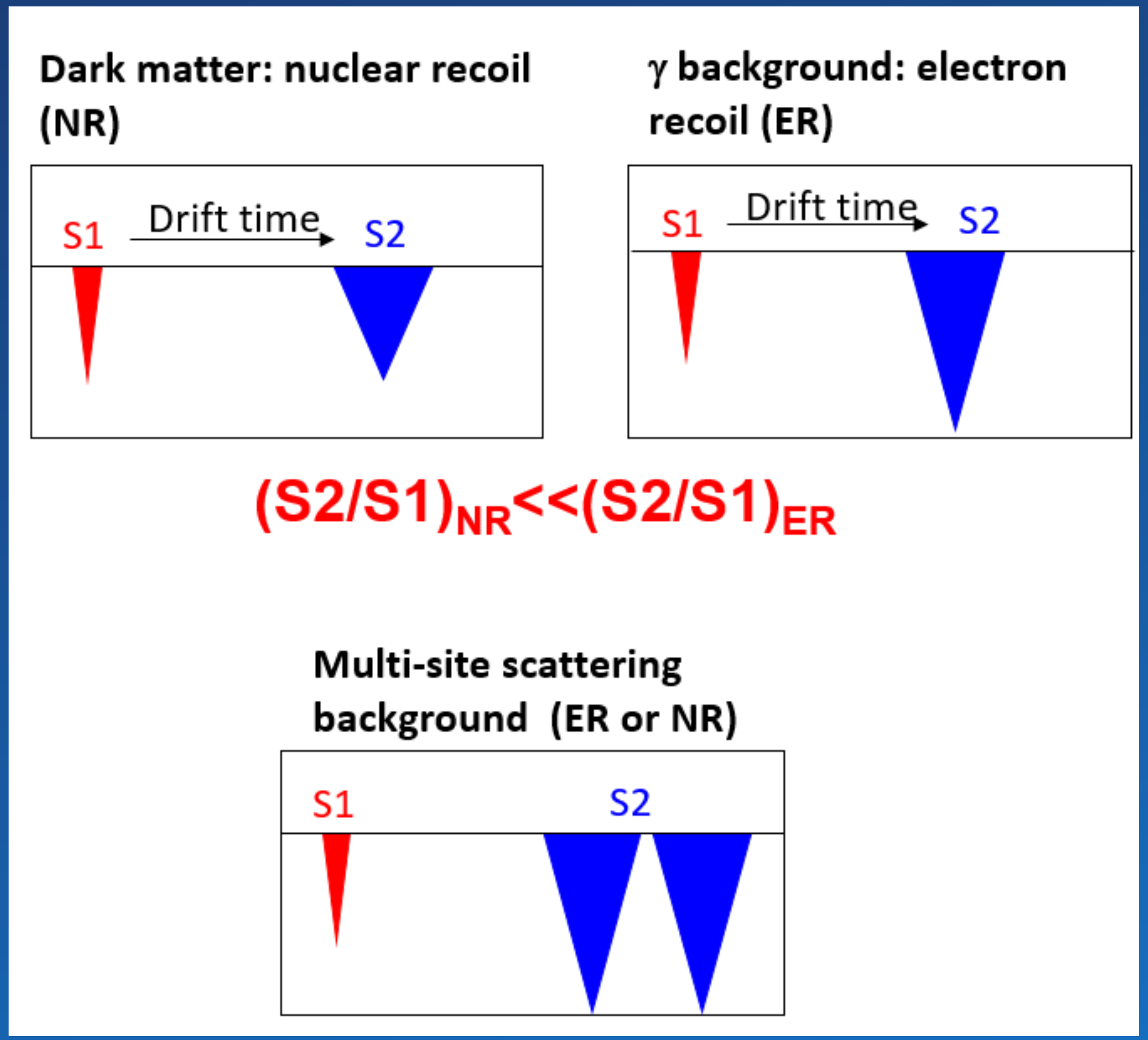
- Event rate approaches a few cnts/100kg/y
- Lowest exclusion at ~8×10^{-47}cm^2 at ~40GeV/c^2
- ~2 orders away from the neutrino floor

PandaX

Dual Phase Xenon Experiment







- Dual phase TPC technology allows:
  1. 3D positioning
  2. Single Scatter selection
- S1 and S2 ratio allows ER/NR discrimination

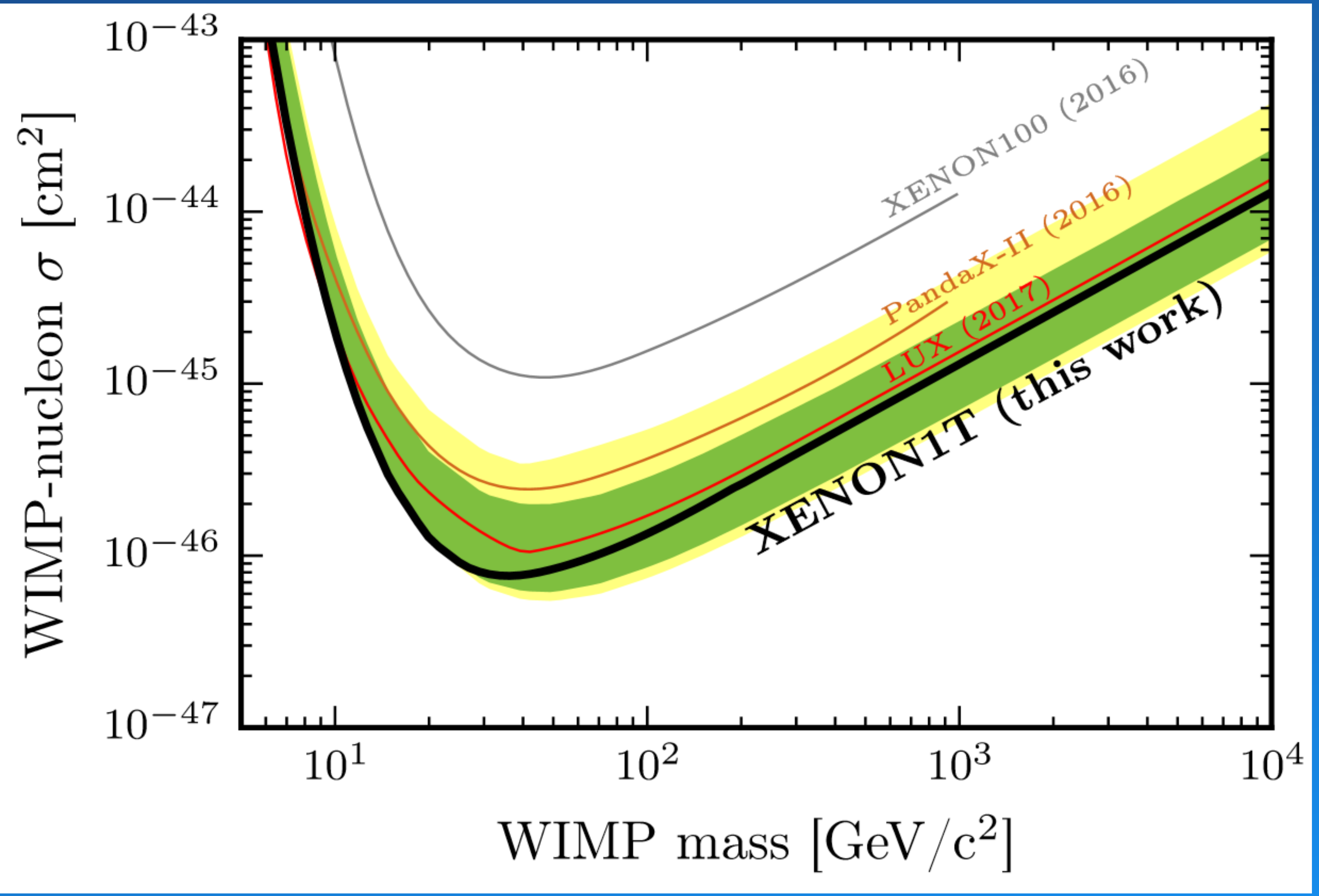
PANDA X

Need three legs to make a table stable

250 kg, concluded 2016,
Sanford Lab
LZ(7-ton) in preparation

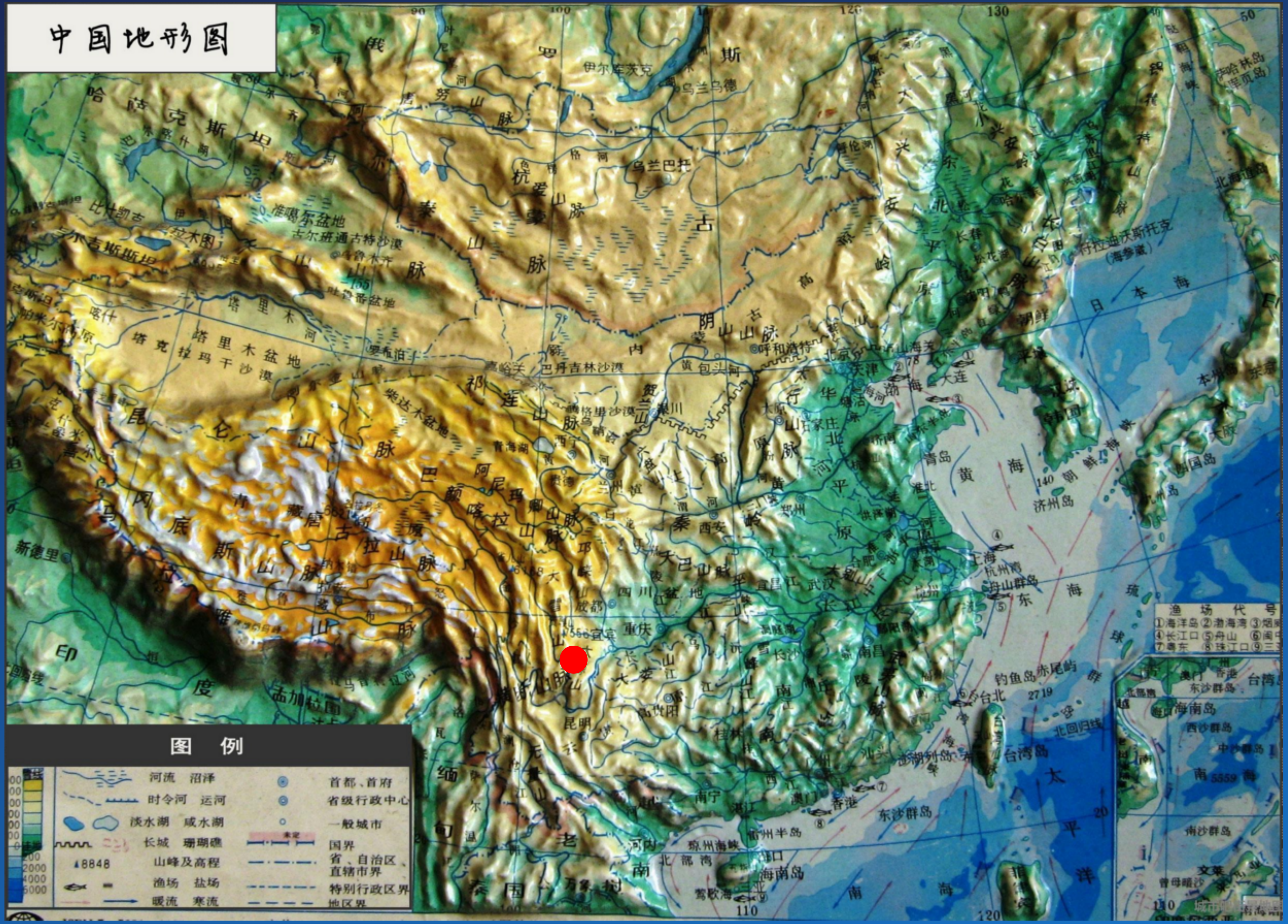
Largest LXe TPC ever built
cylinder: 96 × 97cm
active Xe target 2.0t(3.2t total)
248 PMTs (Hamamatsu R11410-21)

- World leading bkg level: 0.2×10^{-3} evt/day/kg/keV
- First SR: 1024 kg x 34.2 day, no candidate found
- Minimum limit: 7.7 x 10^{-47} cm^2 @ 35 GeV

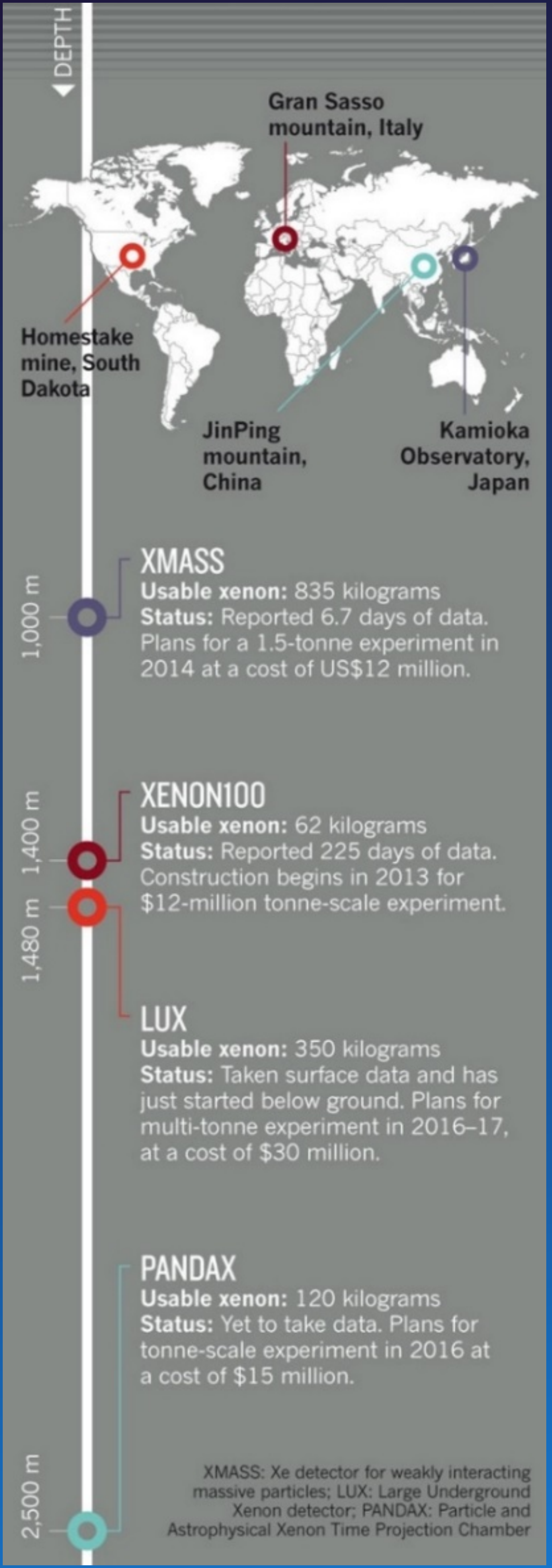


PANDA X

China Jin-Ping underground Lab



China Jin-Ping underground Lab



nature International weekly journal of science

Dark-matter hunt gets deep

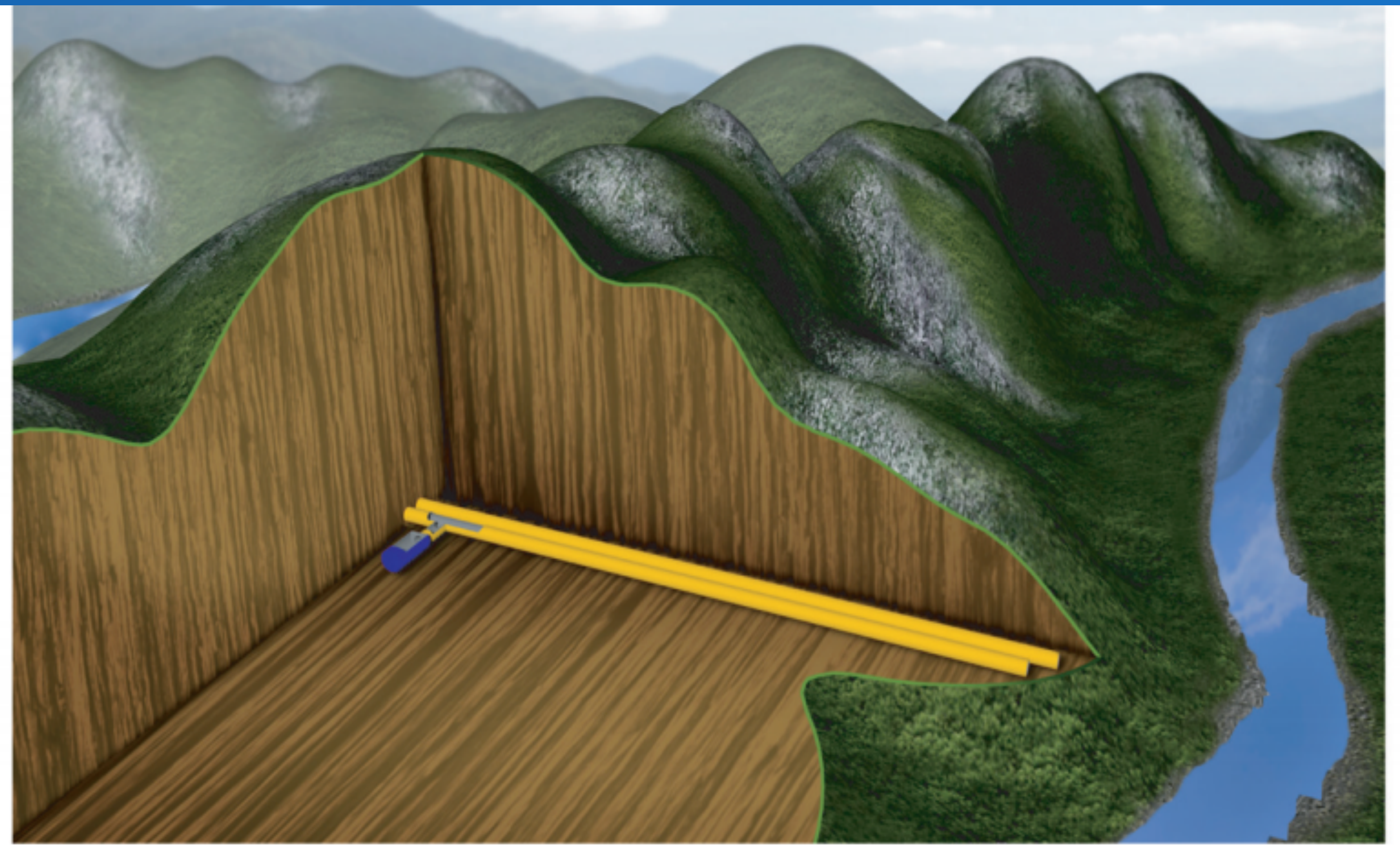
China launches world's deepest particle-physics experiment — but it joins a crowded field.

Eugenie Samuel Reich

20 February 2013 | Corrected: 21 February 2013

NATURE | NEWS

Ongoing experiments in Italy, the United States and Japan are now being joined by a fourth in China, called PandaX (see 'Dark and deep'). Installed in the deepest laboratory in the world, 2,500 metres under the marble mountain of JinPing in Sichuan province, PandaX will this year begin monitoring 120 kilograms of xenon. The team hopes to scale the tank up to 1 tonne by 2016, which would mean that the experiment had developed more quickly than any other dark-matter search. "We want to demonstrate that world-class research in dark matter is possible in China," says Xiangdong Ji, a physicist at Shanghai Jiao Tong University in China and a spokesman for PandaX.



PANDA X

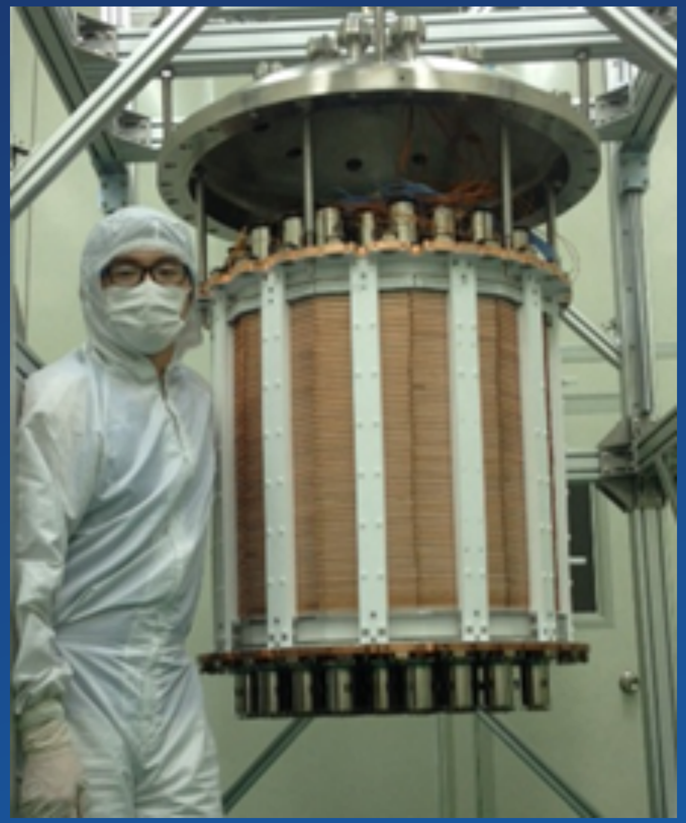
PandaX Collaboration

Started in 2009, ~50 people

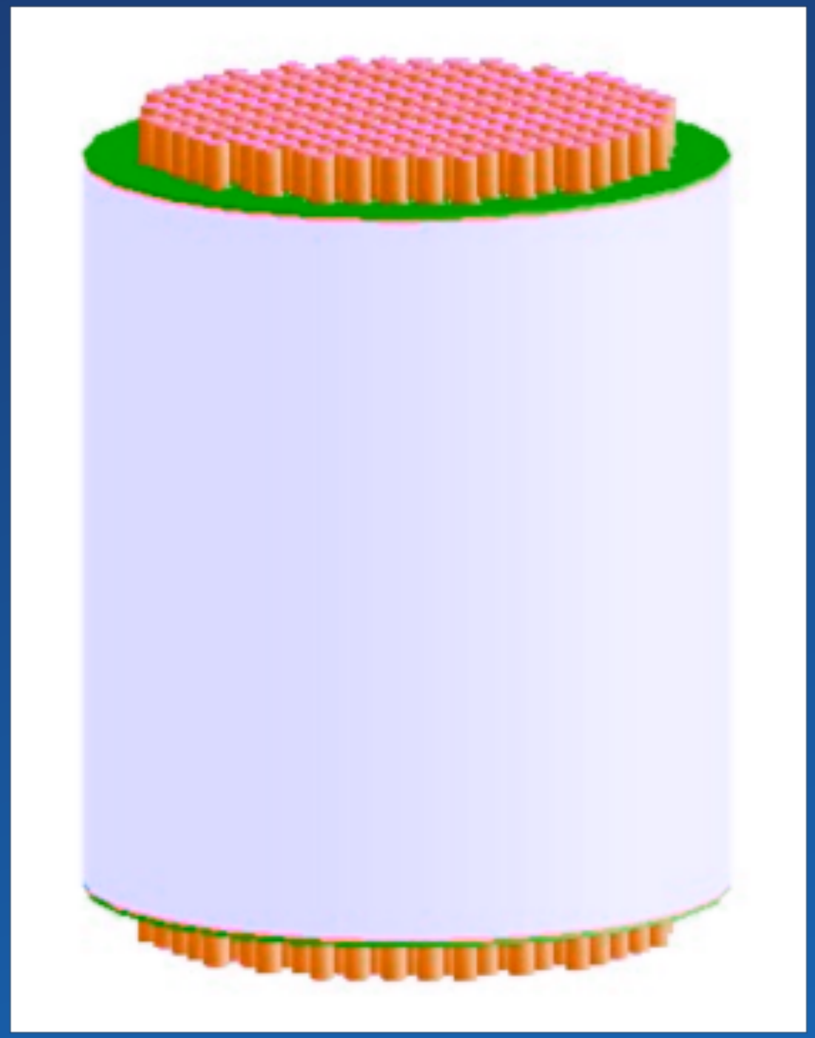
- Shanghai Jiao Tong University (2009-)
- Peking University (2009-)
- Shandong University (2009-)
- Shanghai Institute of Applied Physics, CAS (2009-)
- University of Science & Technology of China (2015-)
- China Institute of Atomic Energy (2015-)
- Sun Yat-Sen University (2015-)
- Yalong Hydropower Company (2009-)
- University of Maryland (2009-)
- Alternative Energies & Atomic Energy Commission (2015-)
- University of Zaragoza (2015-)
- Suranaree University of Technology(2016-)

PandaX Experiments

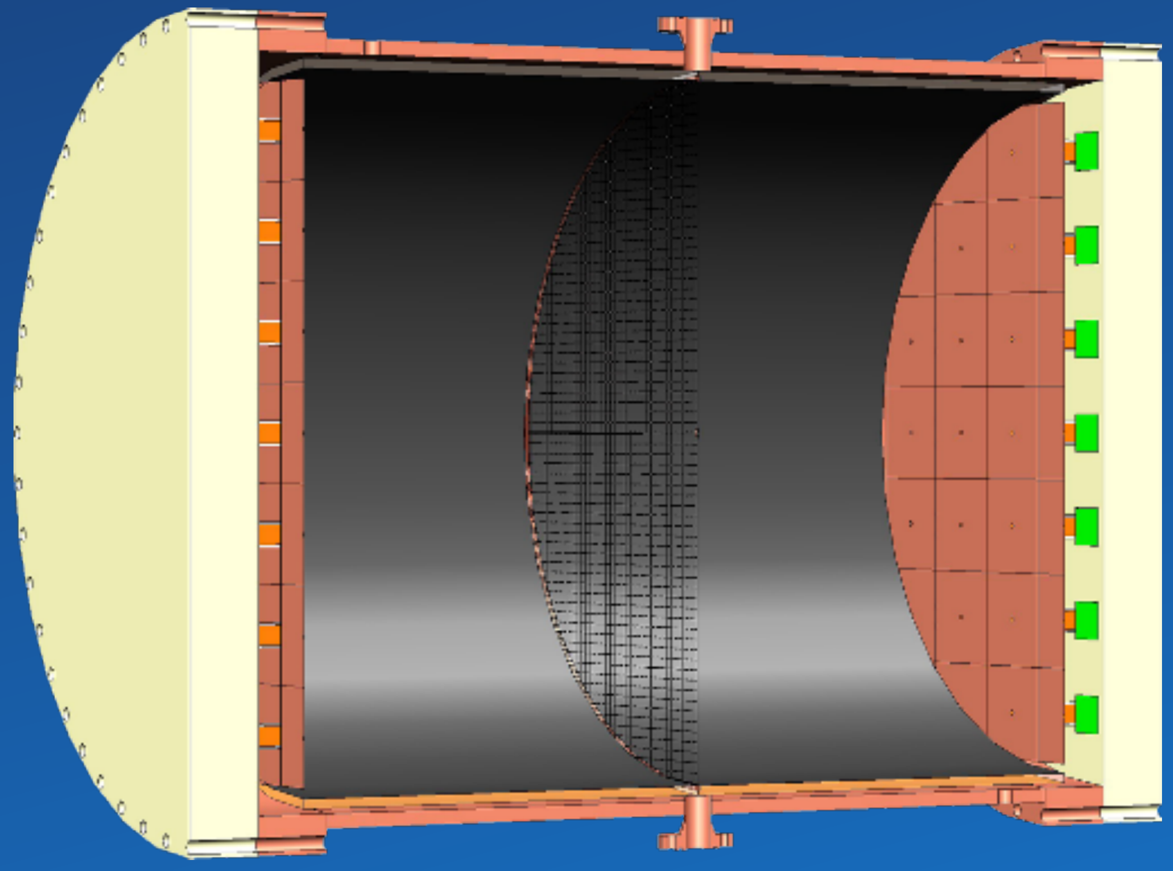
PandaX-I: 120 kg DM experiment
2009-2014



PandaX-II: 580 kg DM experiment
2014-2018



PandaX-xT: multi-ton DM experiment
Future

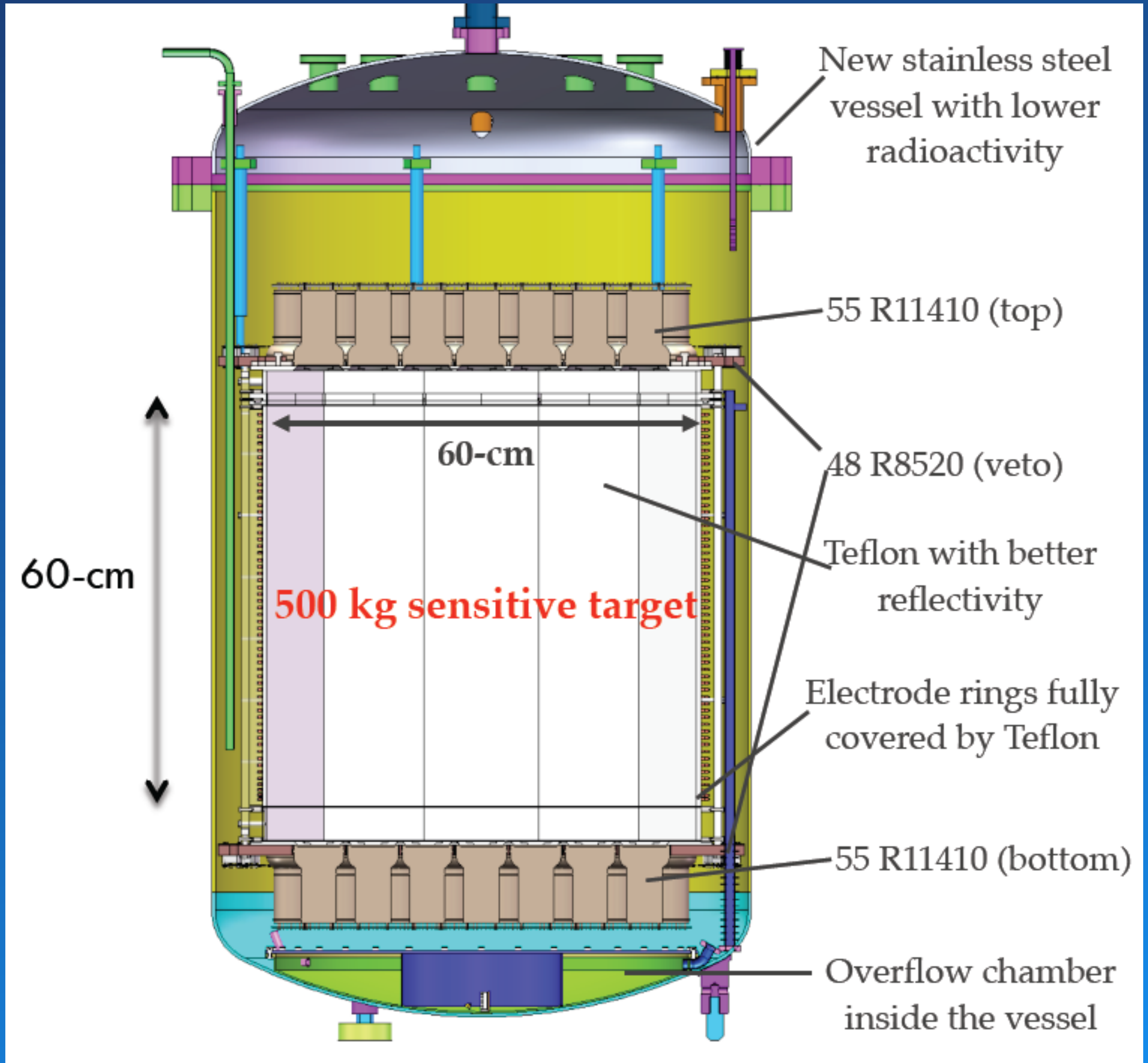


PandaX-III: 200 kg to 1 ton HP gas ^{136}Xe 0vDBD experiment
Future

PANDA X = Particle and Astrophysical Xenon Experiments

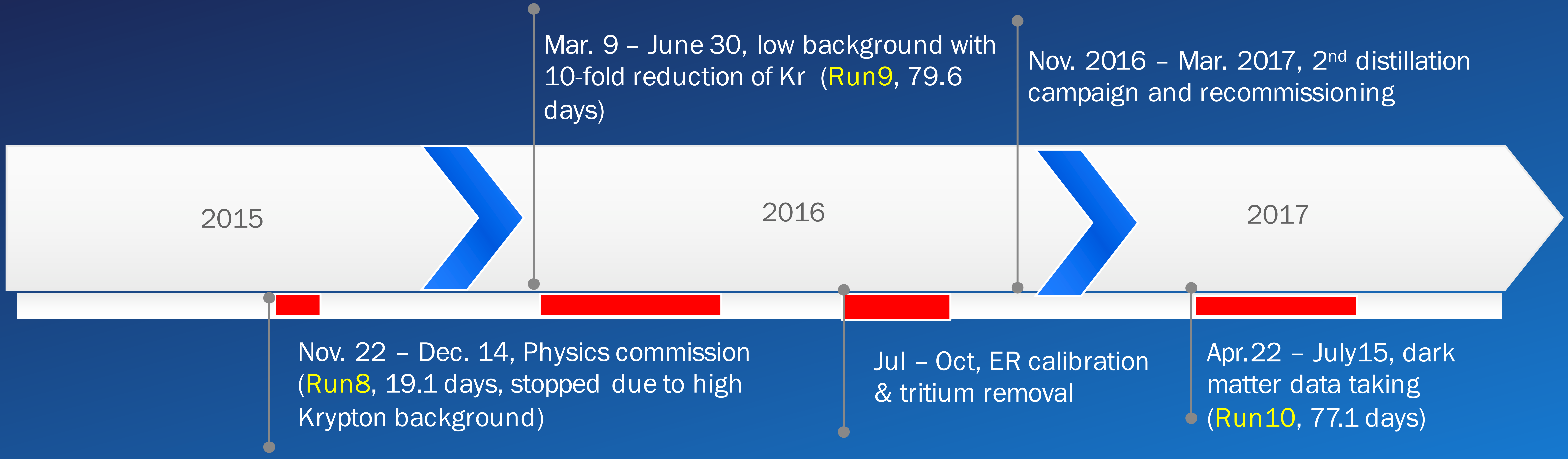
The PandaX-II Detector

- New inner vessel with clean SS
- New and taller TPC
- More 3” PMTs and improved base design with split ±HV power supply
- New isolated skin veto region



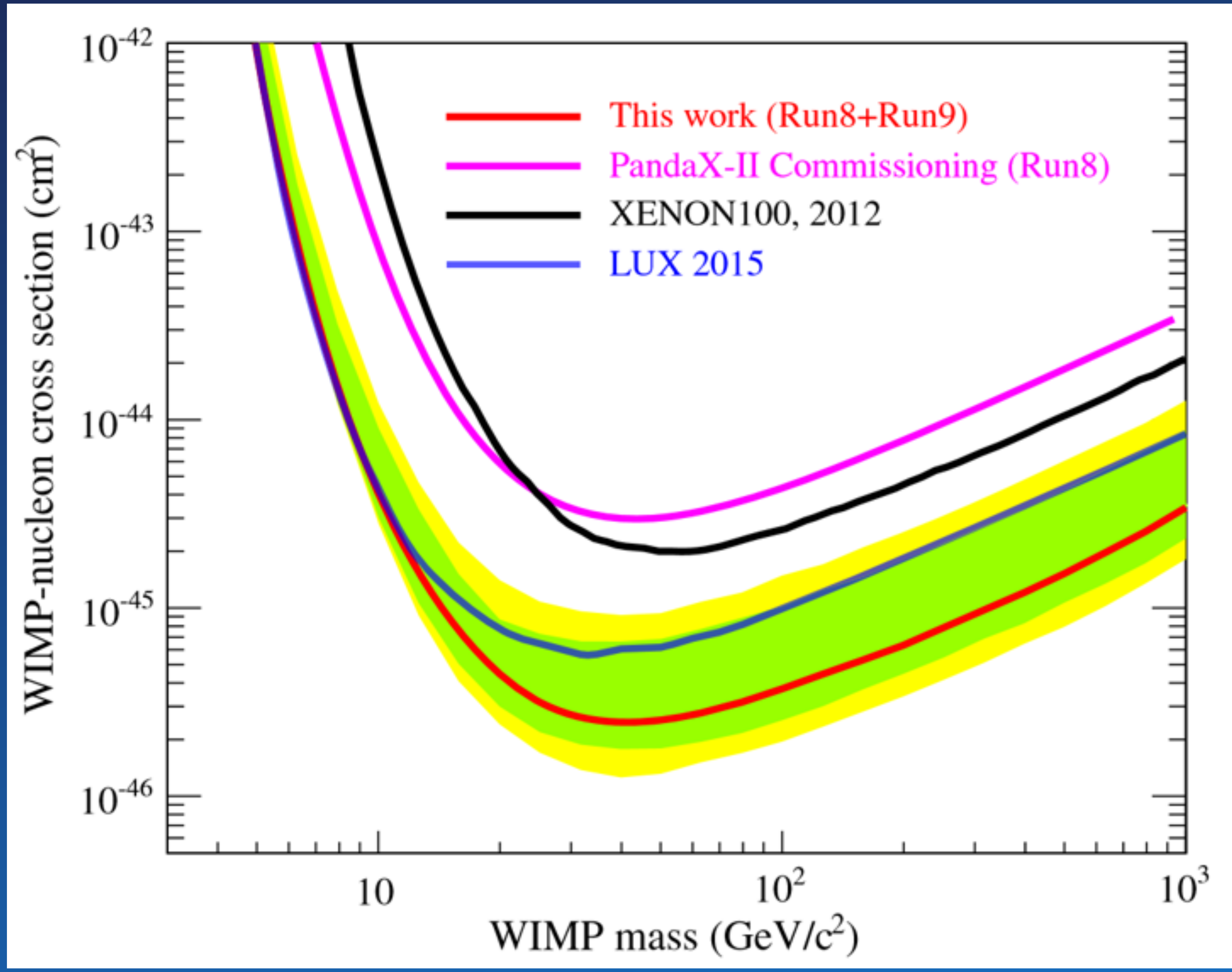
PANDA X

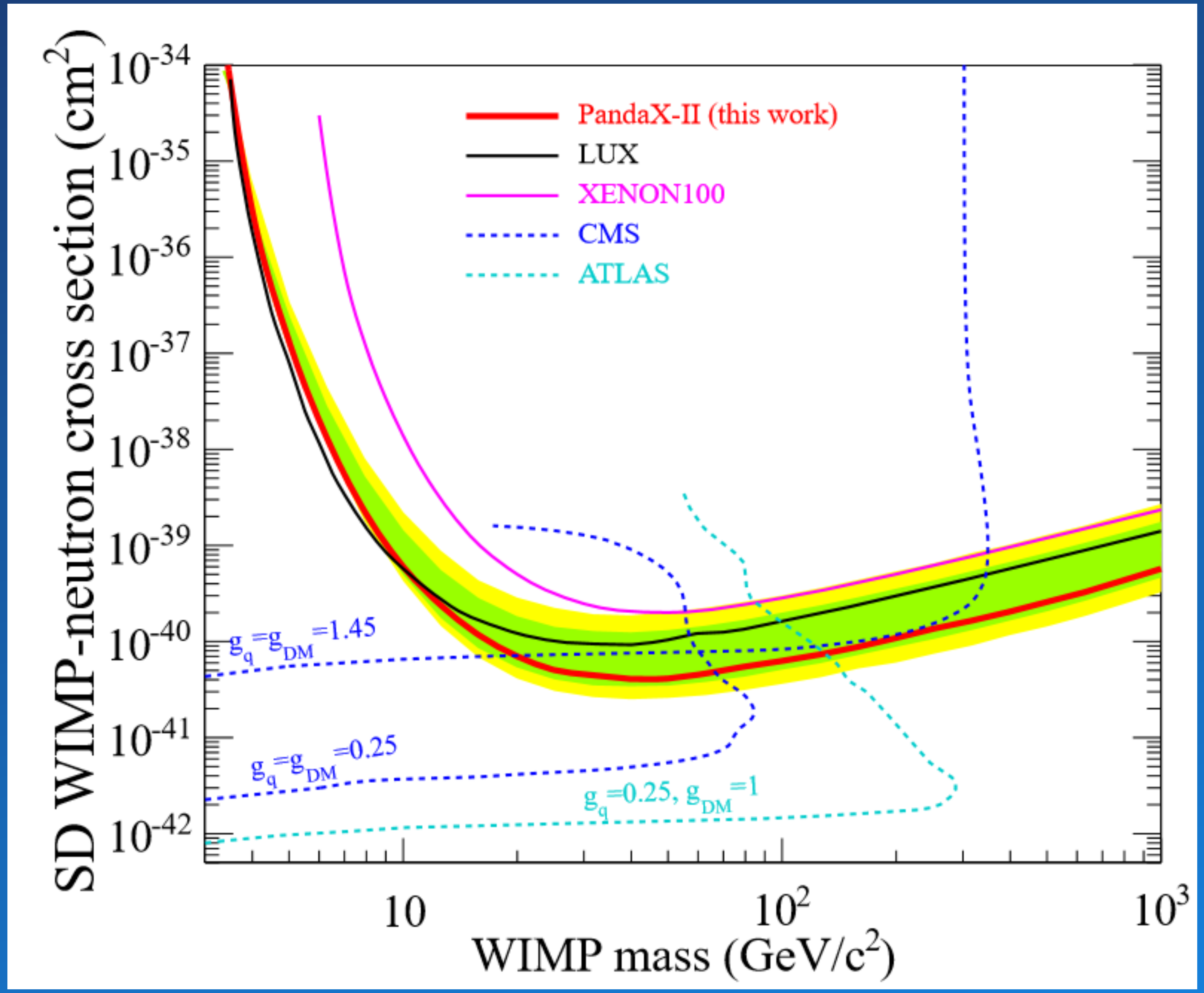
PandaX-II Run History



- Run9 =79.6 days, exposure: 26.2 ton-day
- Run10 =77.1 days, exposure: 27.9 ton-day
- Largest reported DM exposure to date

Run8+9(33 t-day) SI and SD Results





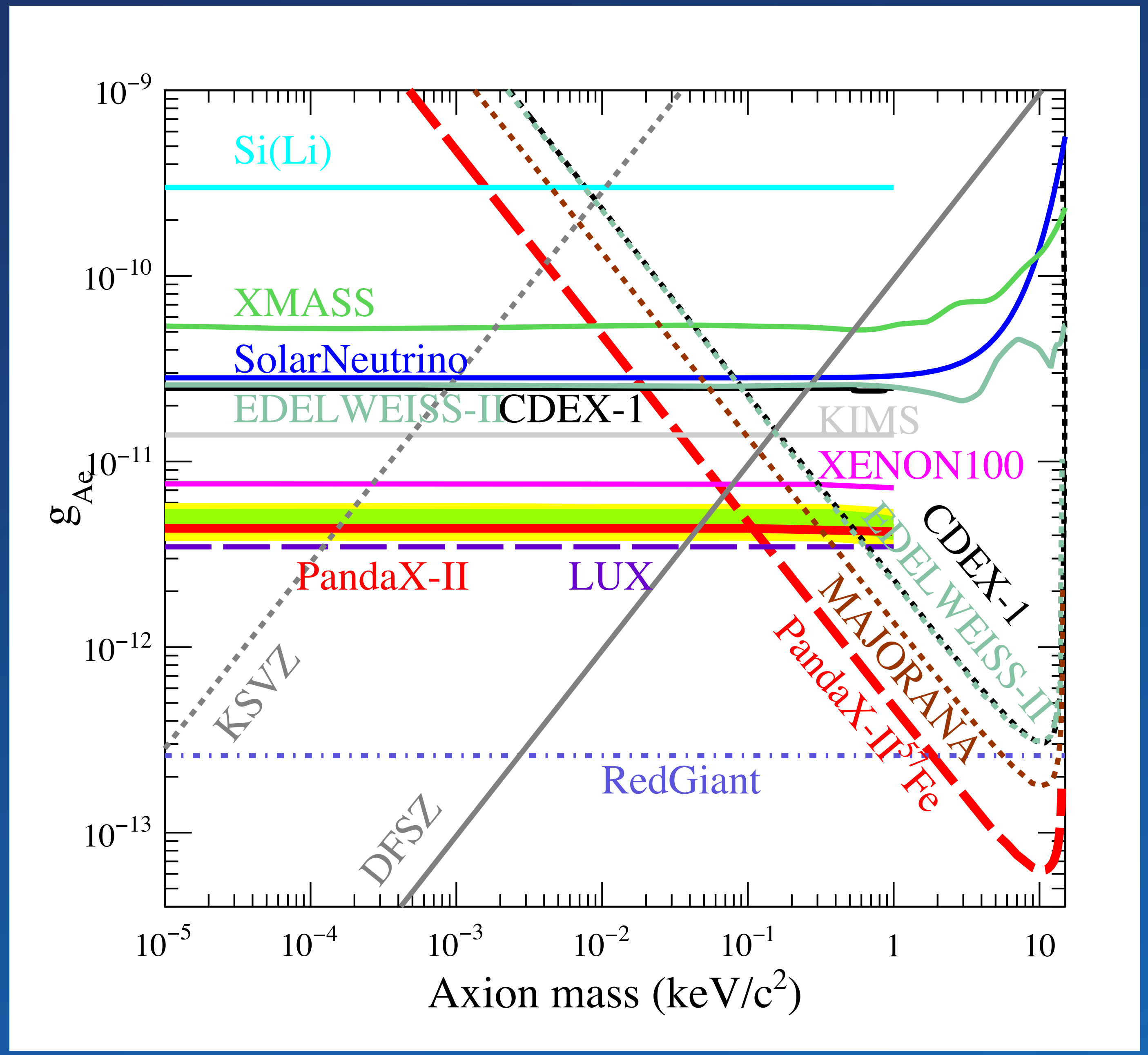
Minimum elastic SI exclusion:
2.5×10^{-46} cm^2 @ 40 GeV/c^2
PRL 117, 121303 (2016)

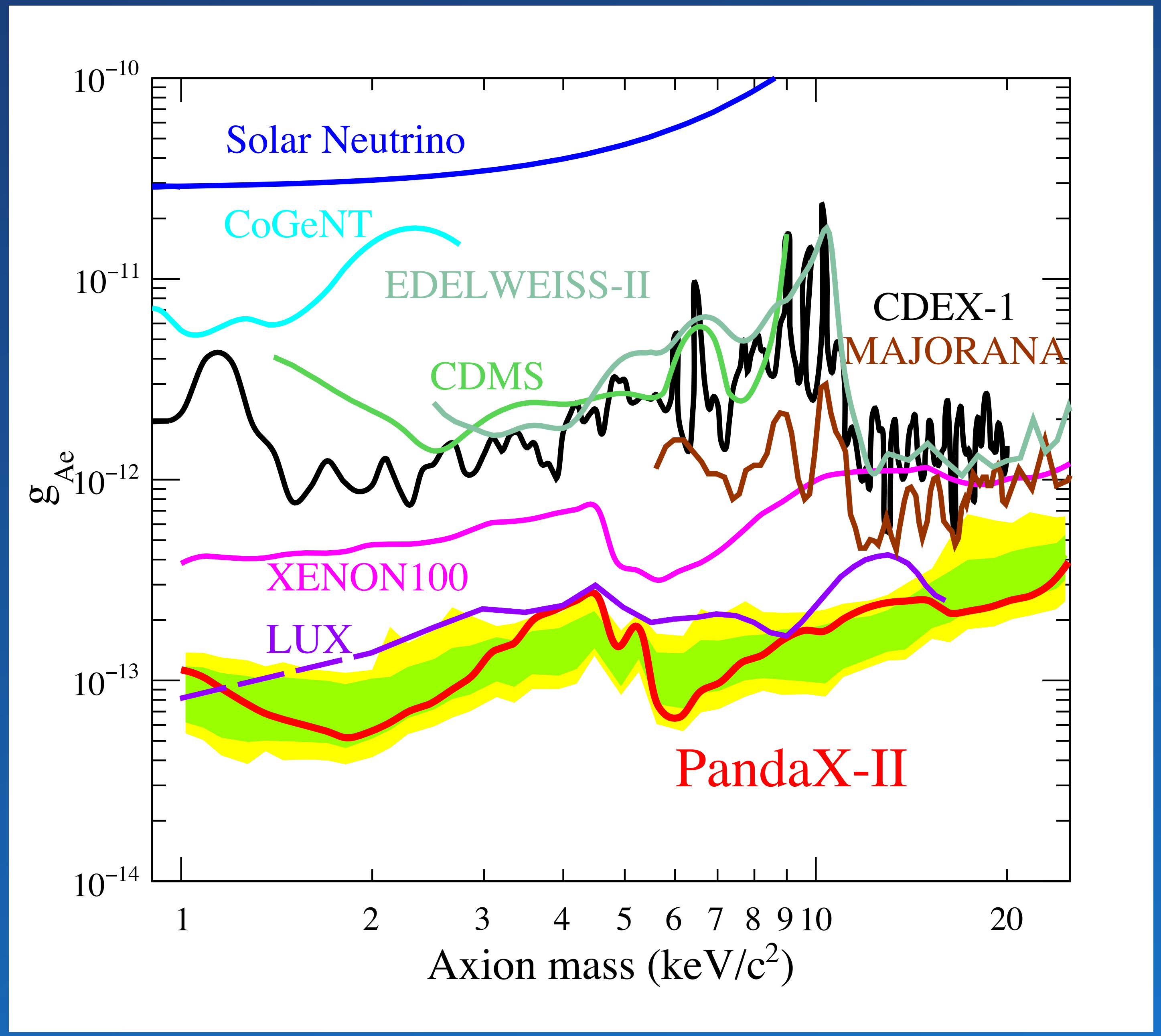
Minimum χ-n SD cross section limit:
4.1×10^{-41} cm^2 at 40 GeV/c^2
PRL 118, 071301 (2017)

PANDA X

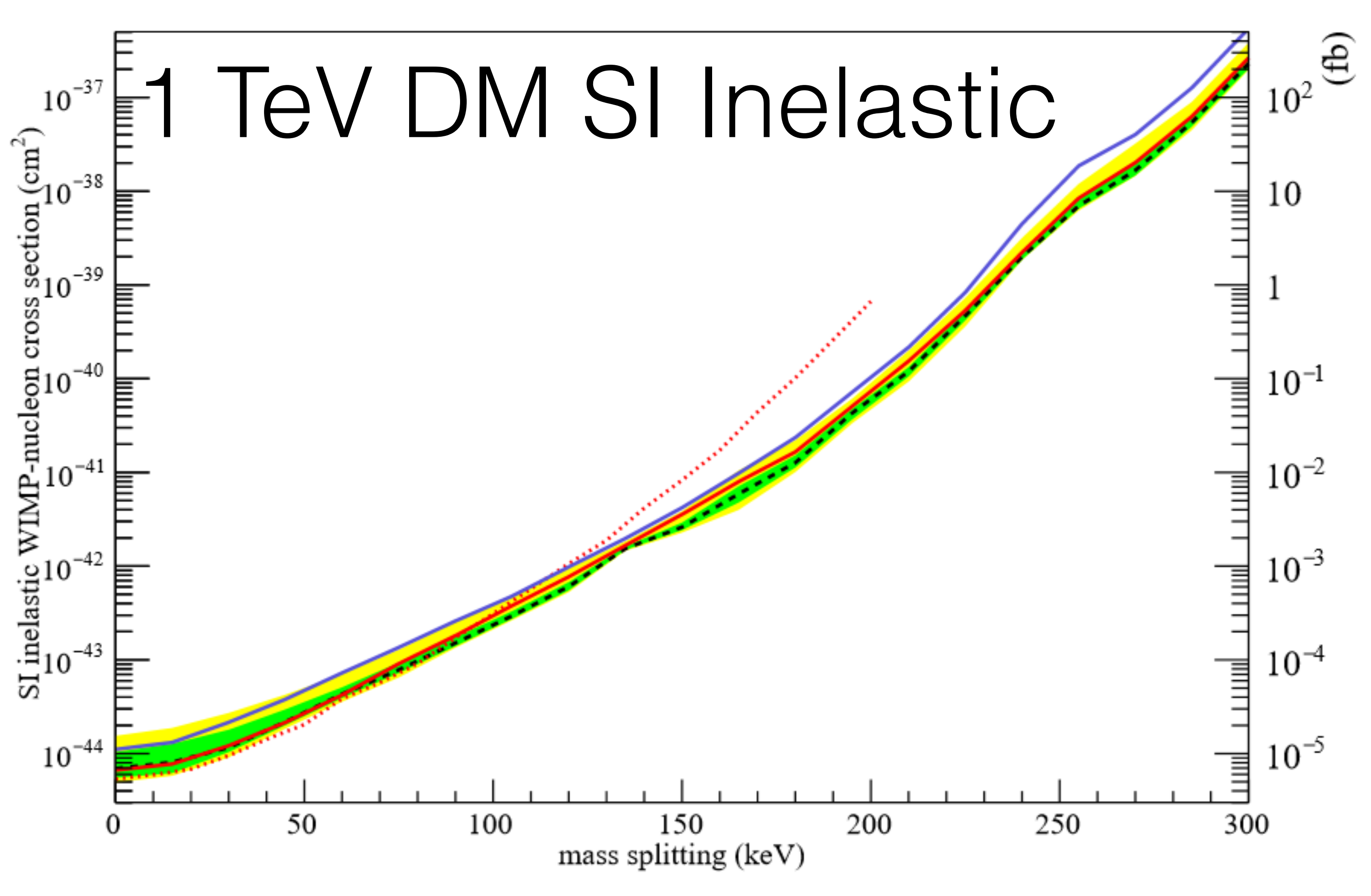
PandaX-II Run9 Axion and Inelastic Results

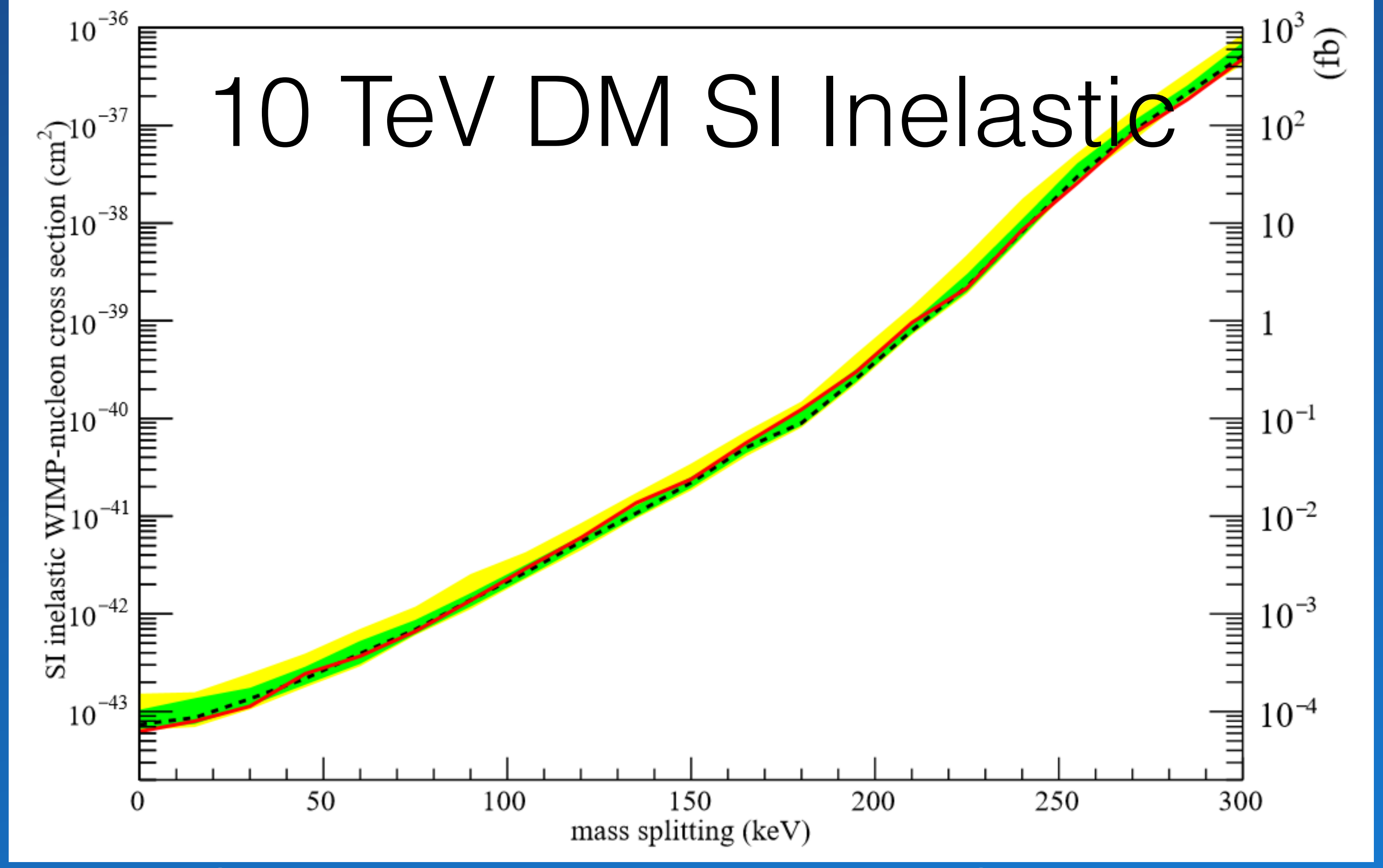
PRL 119, 181806 (2017)





Among the leading axion search on axion-electron coupling using DD experiments





- Opened up energy window to access initial-final mass difference up to 300 keV (high mass DM, ~TeV)
- Tightest direct constraint on this to date (to be published)

PRD 96, 102007 (2017)

2017 new data and results

New SI DM search results from Run10

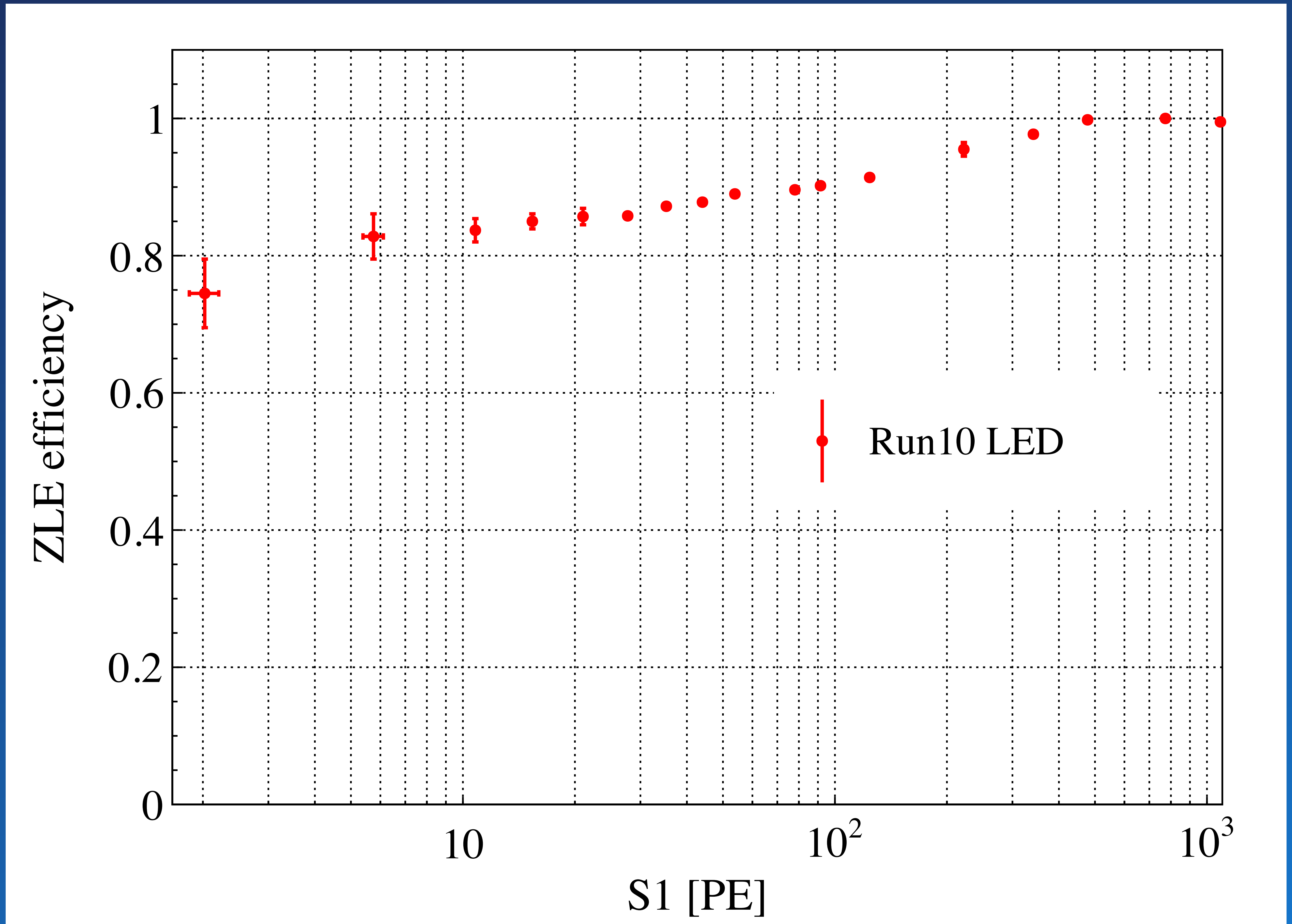
- Improved **trigger** threshold (from 80 to 50 PE≈2 electrons)
- **Calibration**
  - Channel-by-channel SPE efficiency (ε_{ZLE})
  - Improved detector ER/NR response model
- 2.5 times reduction in total **background**
  - Kr85 ↓6 times
  - Accidental ↓ 3 times
  - Xe127 ↓13 times

PANDA X

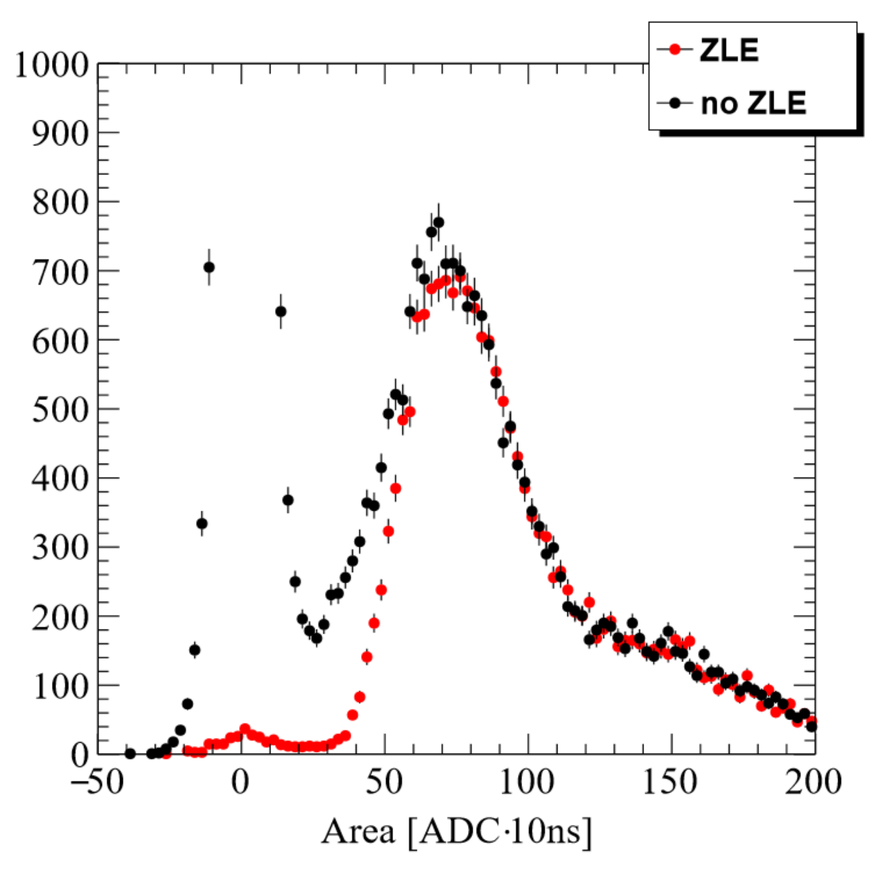
Calibration Program

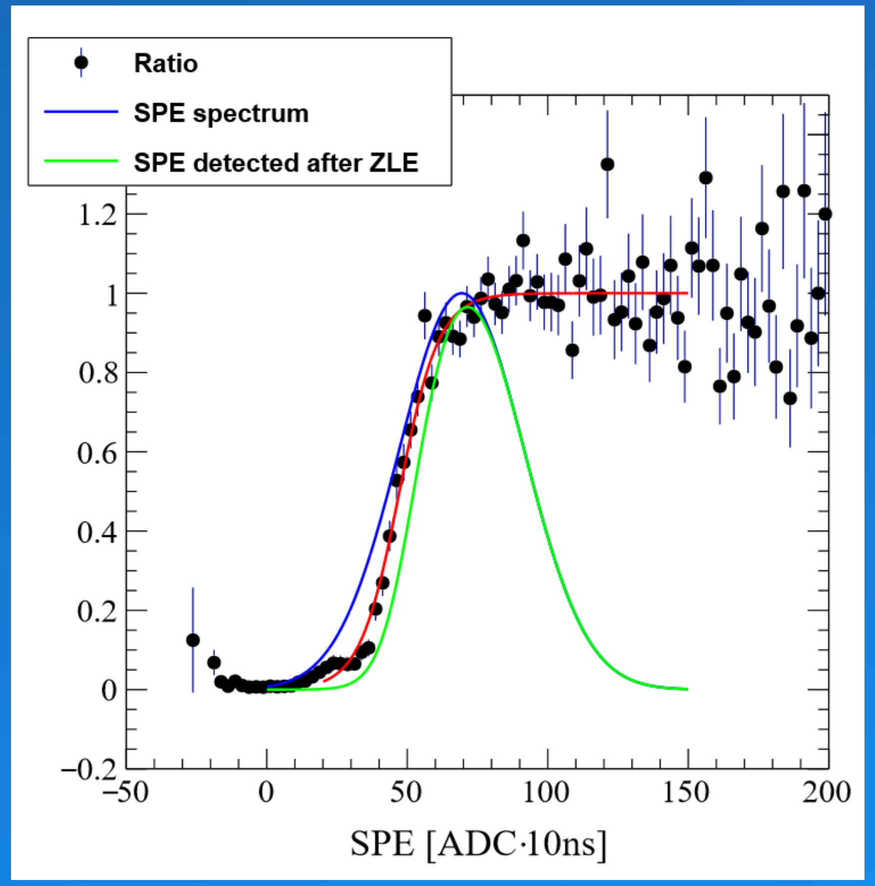
- Gain Calibration
- ZLE Efficiency on S1 and S2
- Uniformity correction and Energy reconstruction
- NR Calibration using $^{241}AmBe$
- ER calibration using CH_3T

Cali: Overall ZLE efficiency by LED Vs. S1



- Average efficiency measured at 3 PE (S1 threshold) was about 80% using blue LED
- PMT Double-PE emission would further improve the efficiency
- Little impact to S2, little impact to position reconstruction

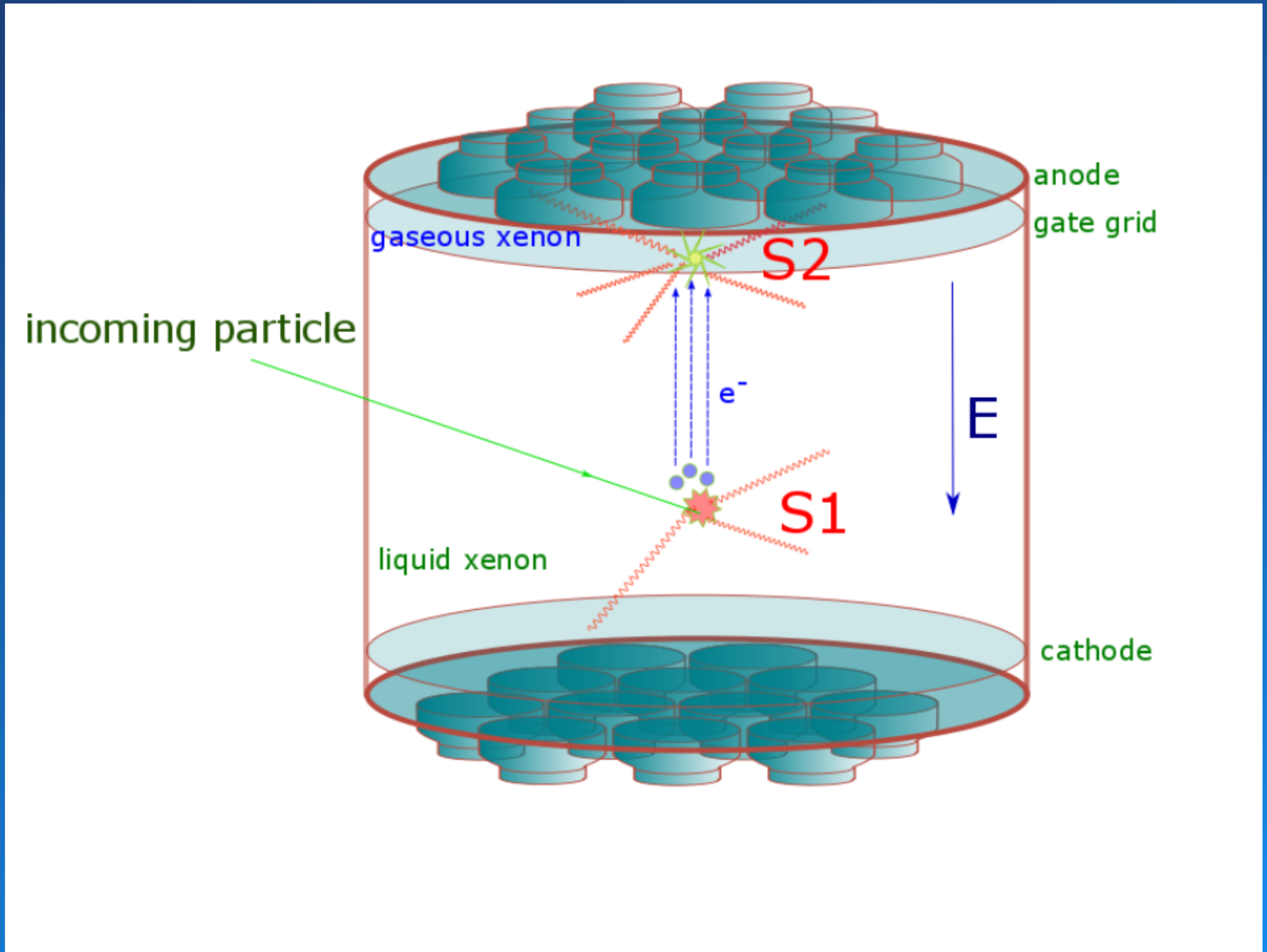




PandaX

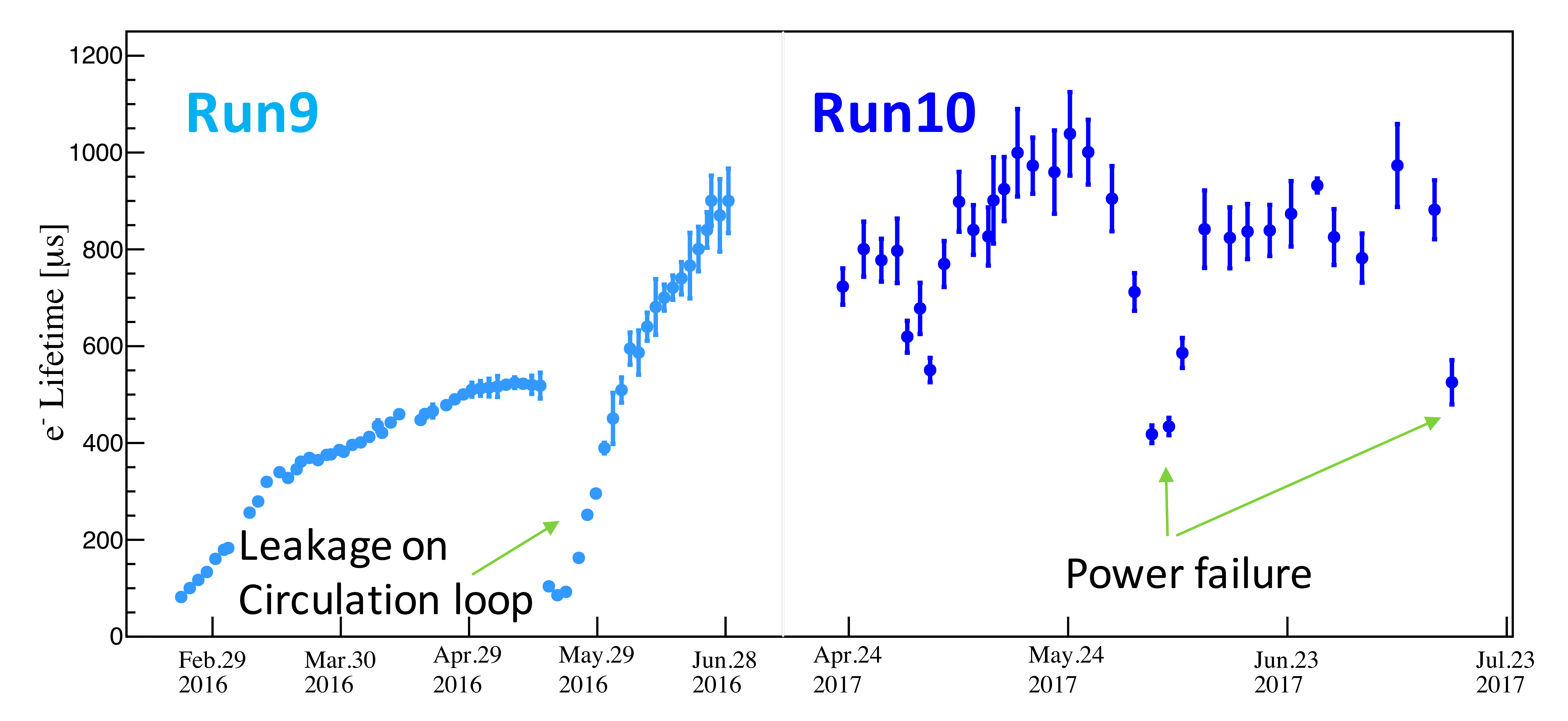
Cali: Uniformity Correction

- Z correction on S2
  - electron absorption to electronegative impurities
- X-Y correction on S2
  - geometry
  - Field non-uniformity
- 3D correction on S1
  - geometry
  - Rayleigh Scatter
  - Light attenuation



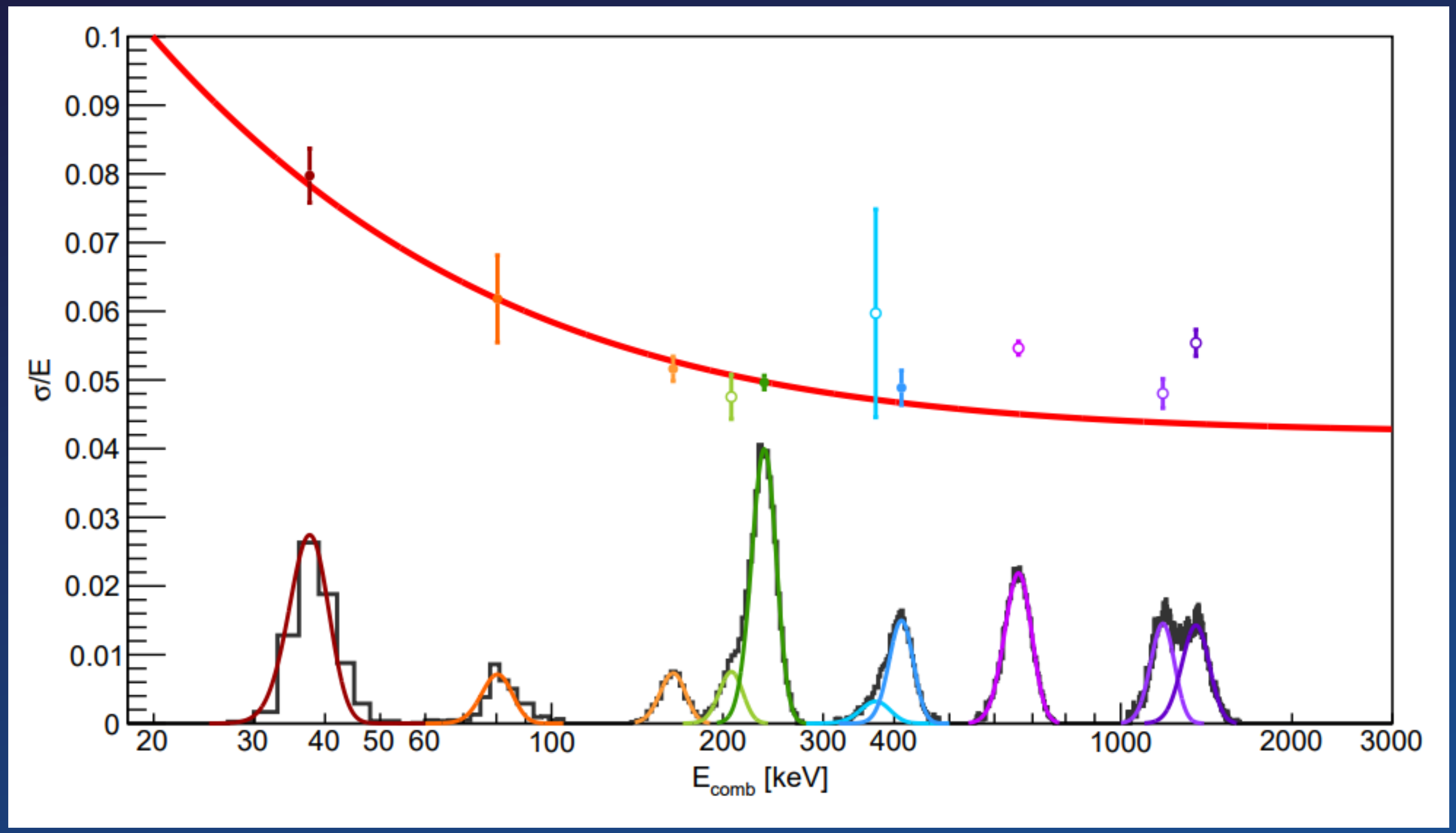
PANDA X

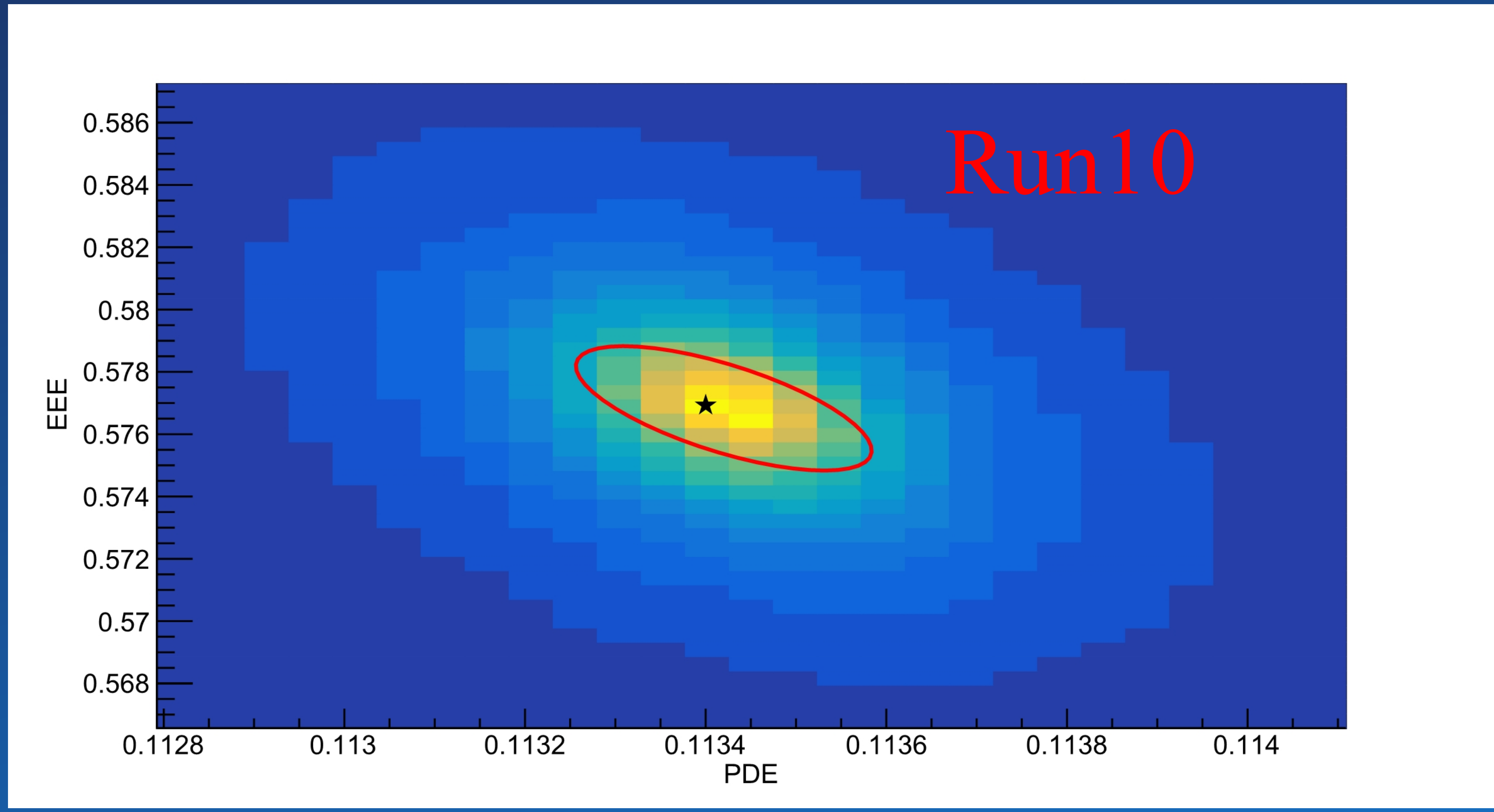
Cali: Election Lifetime



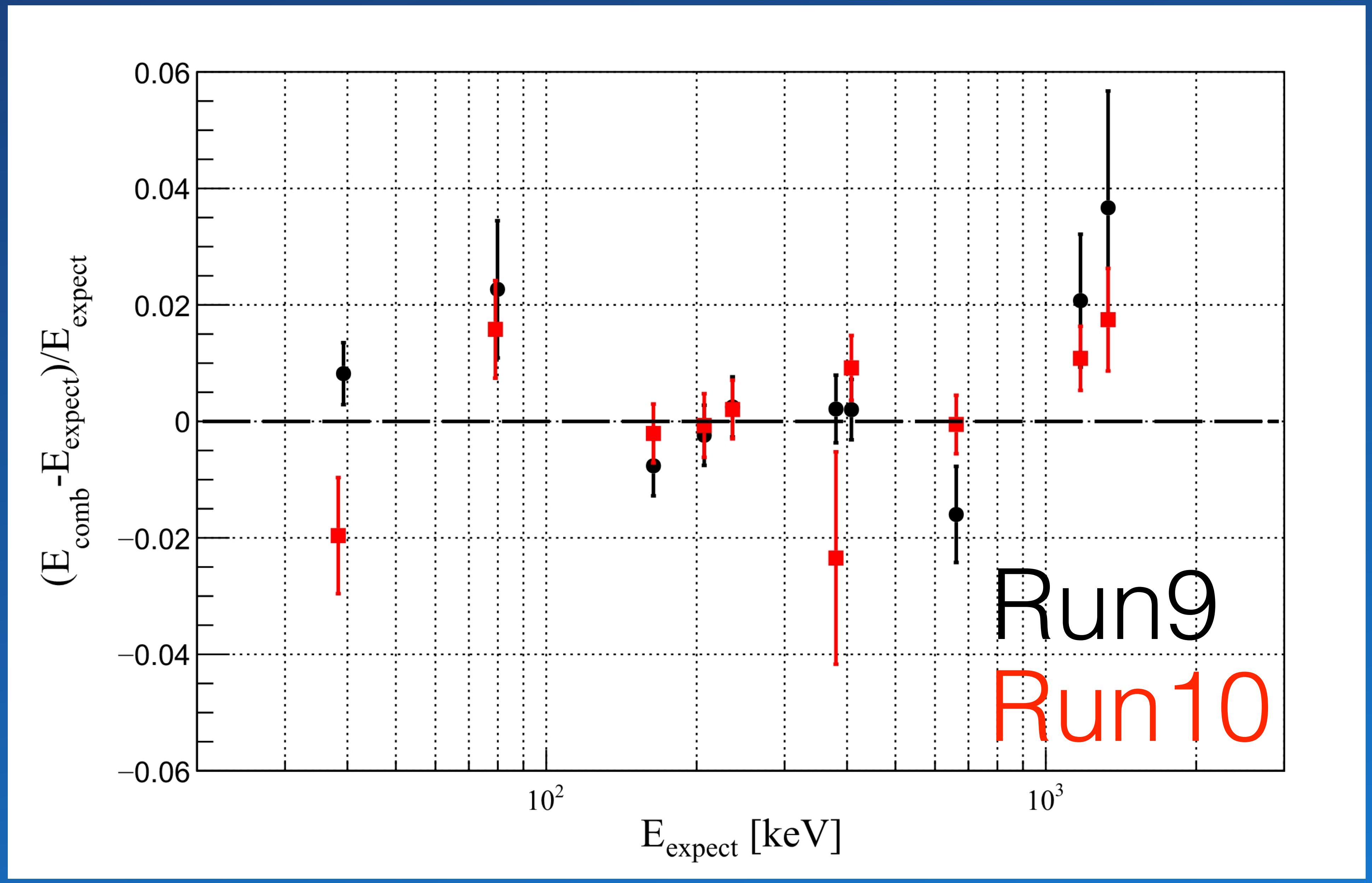
- Electron lifetime on average 800μs (1.4 m drift distance) in Run10, and generally stable
- Significantly improved from Run9

Cali: Energy Reconstruction





$$E_{ee} = W \times \left(\frac{S1}{\boxed{PDE}} + \frac{S2}{\boxed{EEE} \times \boxed{SEG}} \right)$$

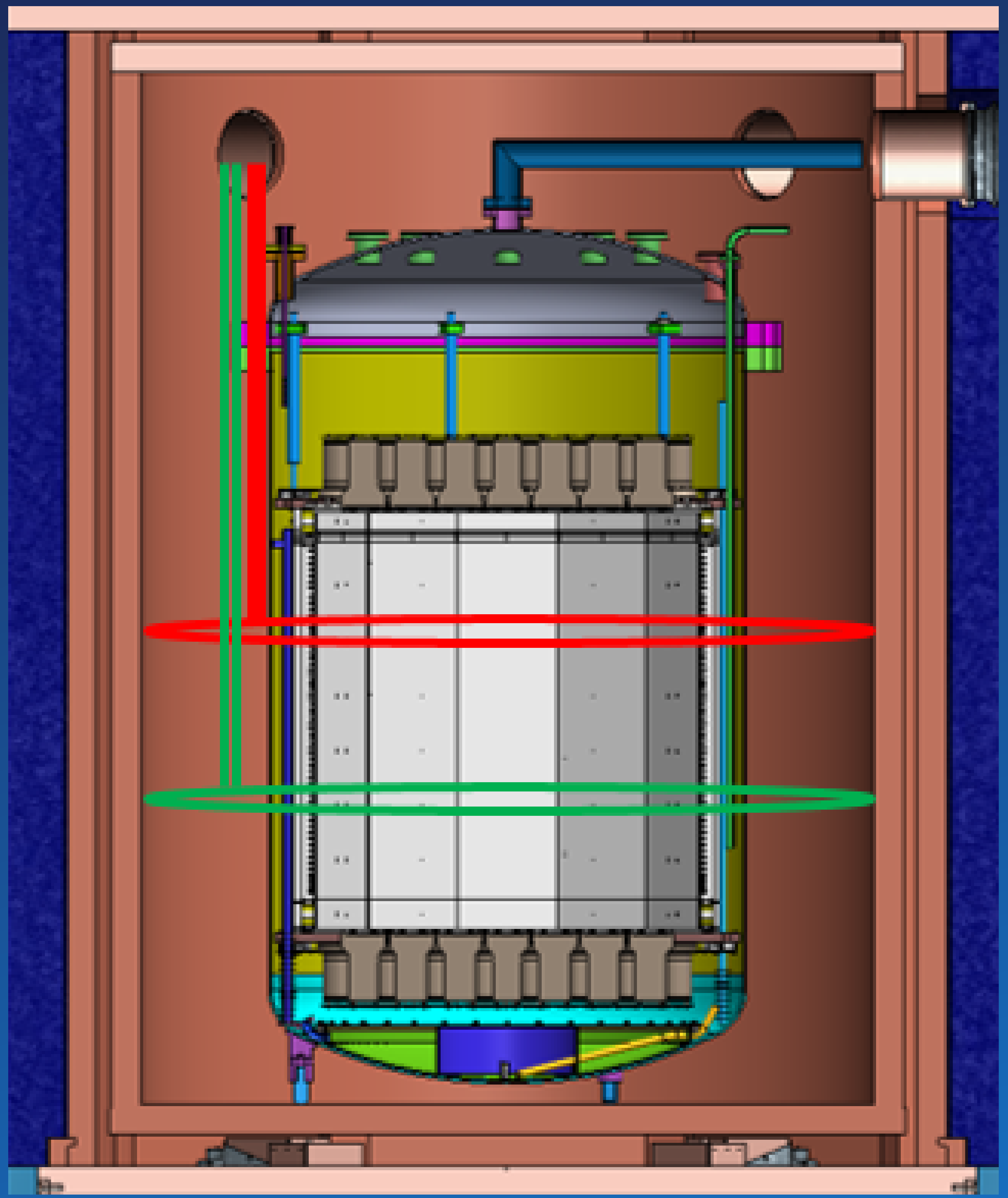


For this analysis

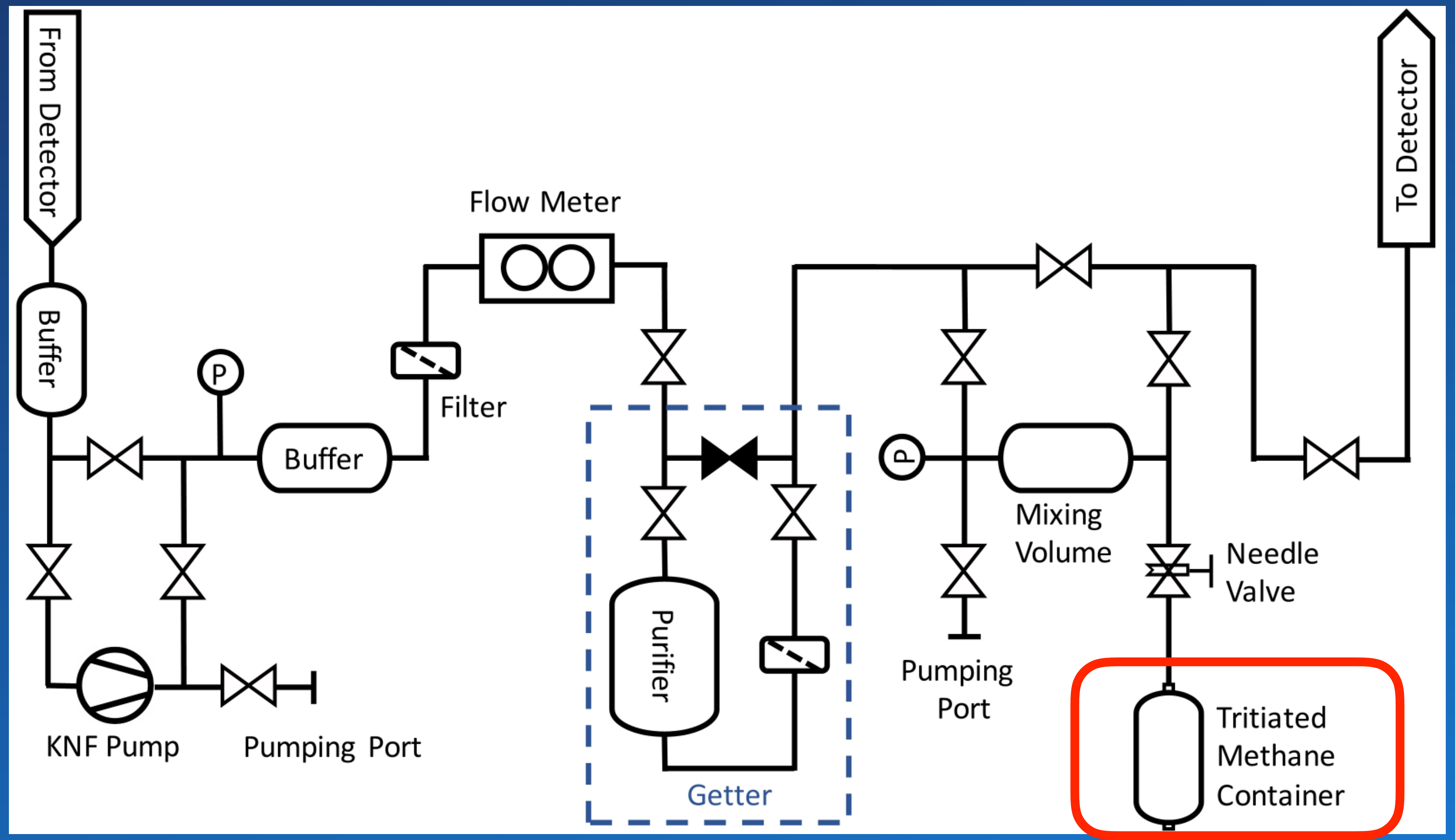
- SEG determined with ZLE efficiency taken into account
- Utilized a more careful treatment for the S2 saturation
- Resulting best fit <2% with expected energies

PandaX

Cali: ER and NR

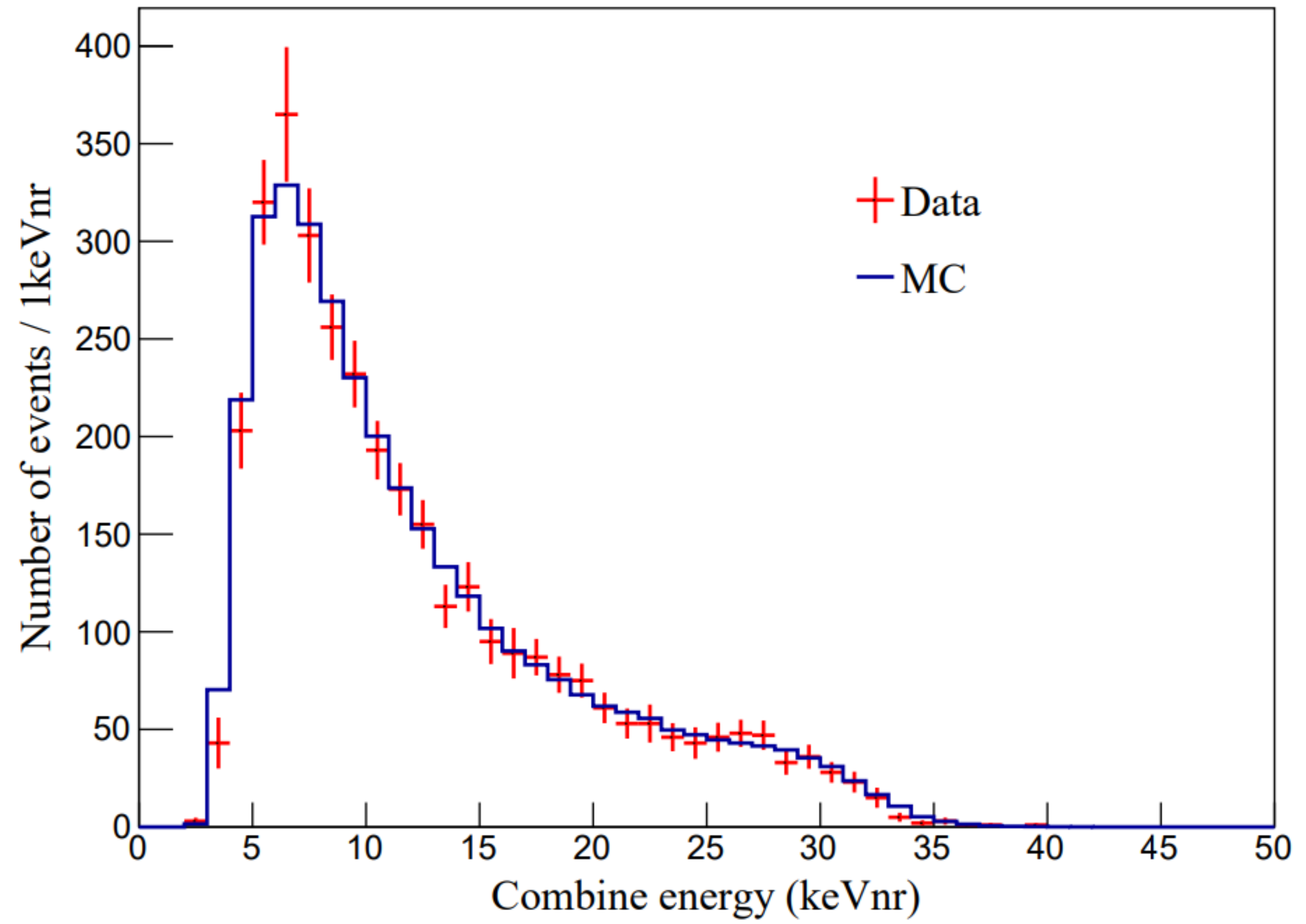


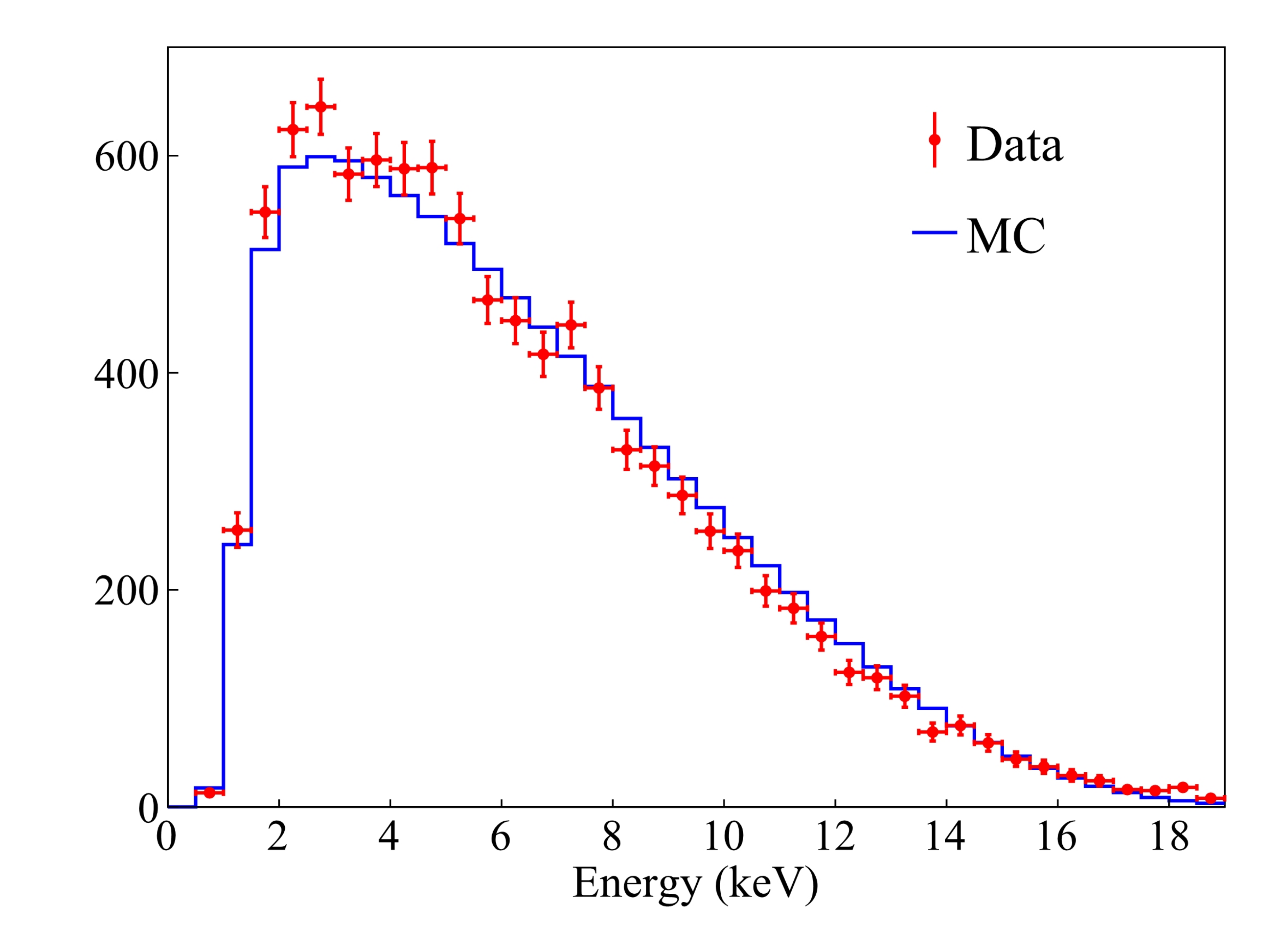
Neutron calibration:
AmBe source deployed



- ER calibration using tritiated methane (pioneered by LUX)
- Selected data with electron lifetime ~700 s, ~8000 low energy ER events

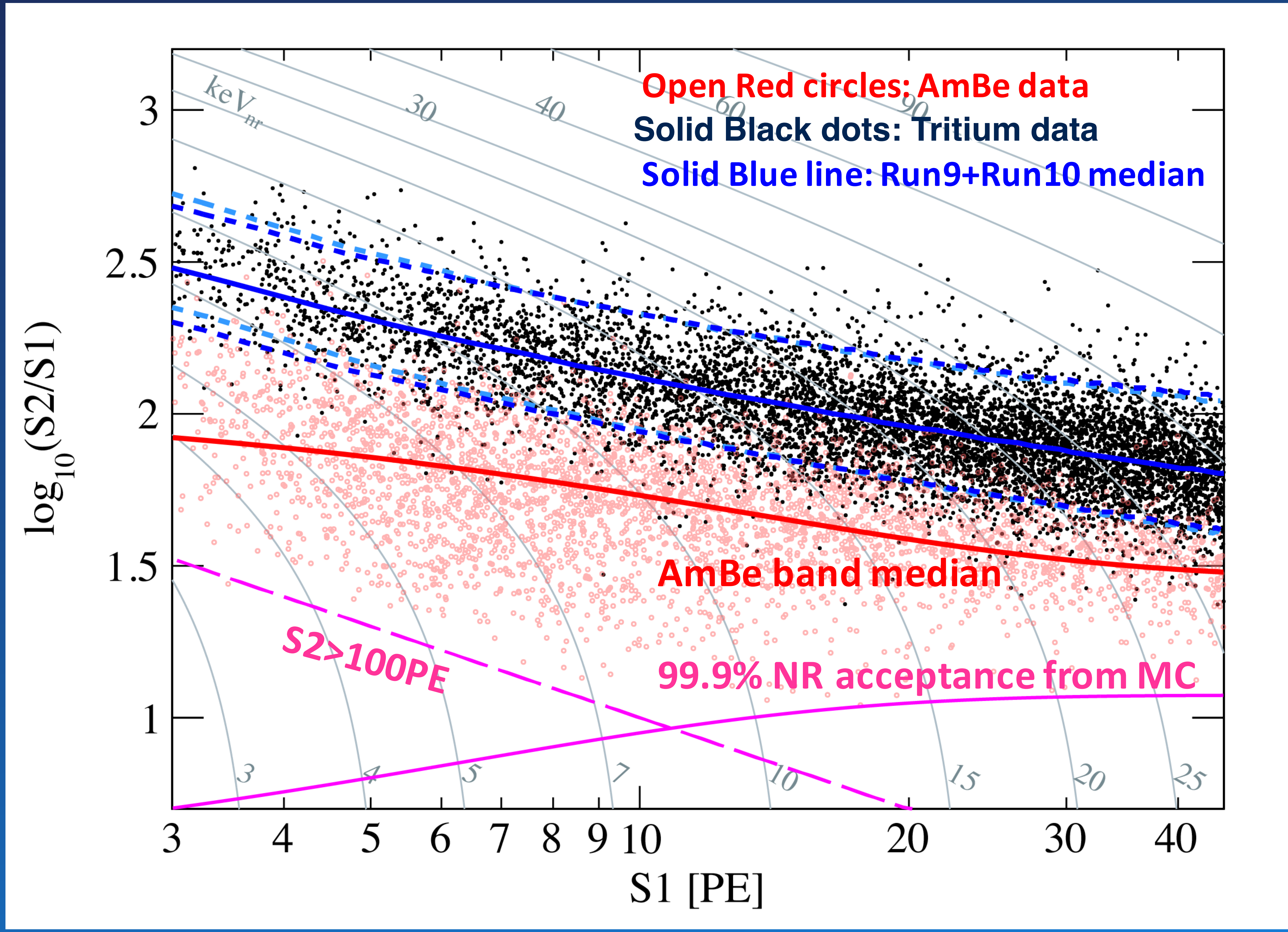
Data/model comparison(example)





- A tuning of the N_{ex}/N_i (excitation/ionization) parameter was made on the NEST model, after which data and MC yield good agreement
- Consistent efficiencies obtained using ER/NR calibrations

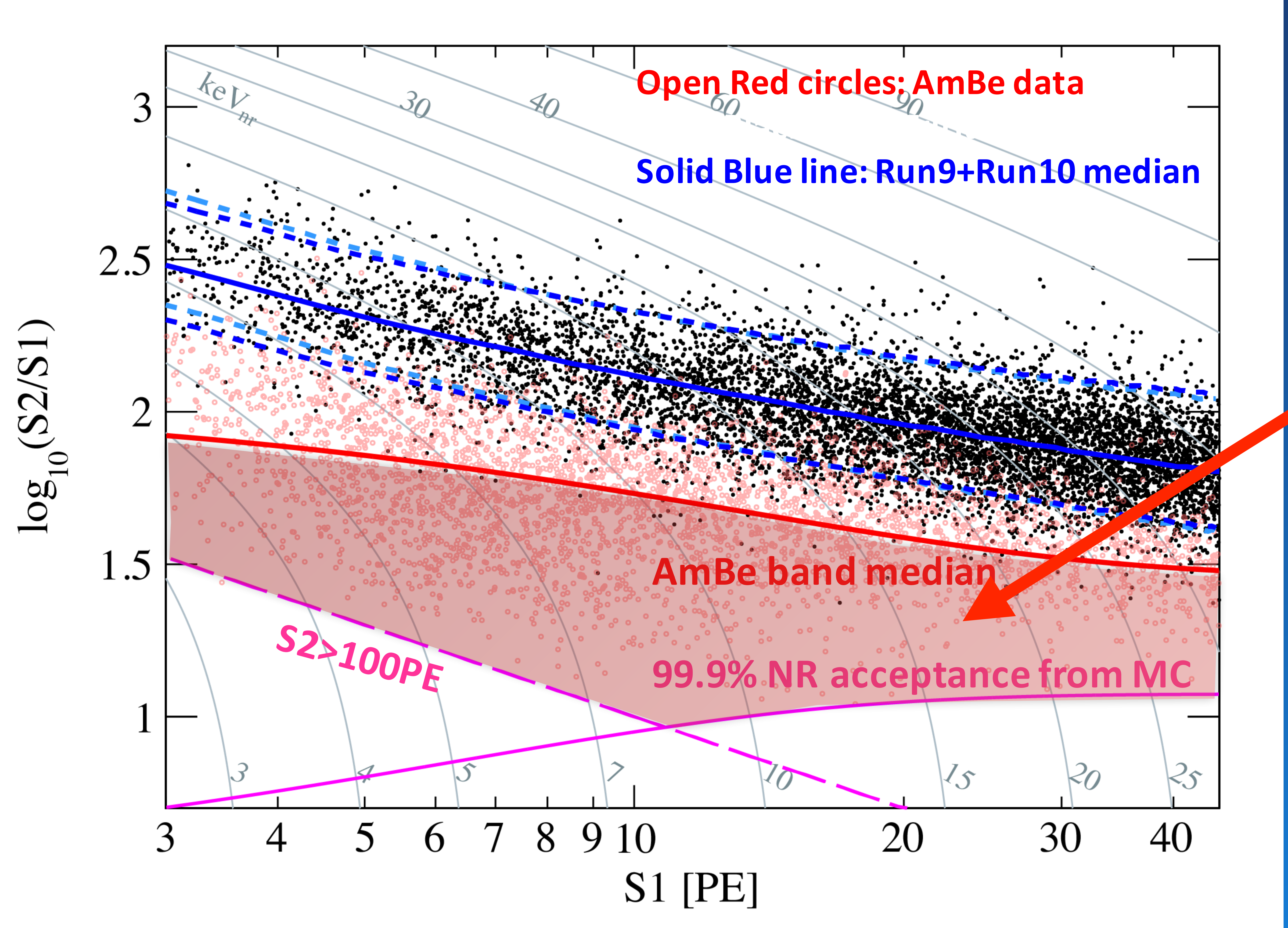
Cali: Direct comparison of ER and NR bands



- Events leaked below the NR median: 0.53(8)%

PandaX

Calibration to Background



Game of Thrones: Background level

We want keep as clean as possible in this region and waiting for DM scattering events

BKG: 2nd distillation campaign

- After ER calibration, realized that the getter could not remove tritium background effectively
- Suspected tritium attached to wall, emanation rate balance with removal rate
- 2nd distillation campaign (for Kr and tritium)
- Nov. – Mar 2017: **recuperate distillation refill,** flush (closed) detector with warm xenon

First beneficial occupancy of CJPL-II!

PANDAX

Background level

	Run9	Run10
Xe127	0.42	0.021
Tritium	0	0.27
Kr85	1.19	0.20
Rn222	0.13	0.12
Rn220	0.01	0.02
Detector ER	0.20	0.20
Solar neutrino	0.01	0.01
Xe136	0.0022	0.0022
Total	1.96	0.79

Original ^{127}Xe gone, additional introduced by a bottle of surface xenon during distillation

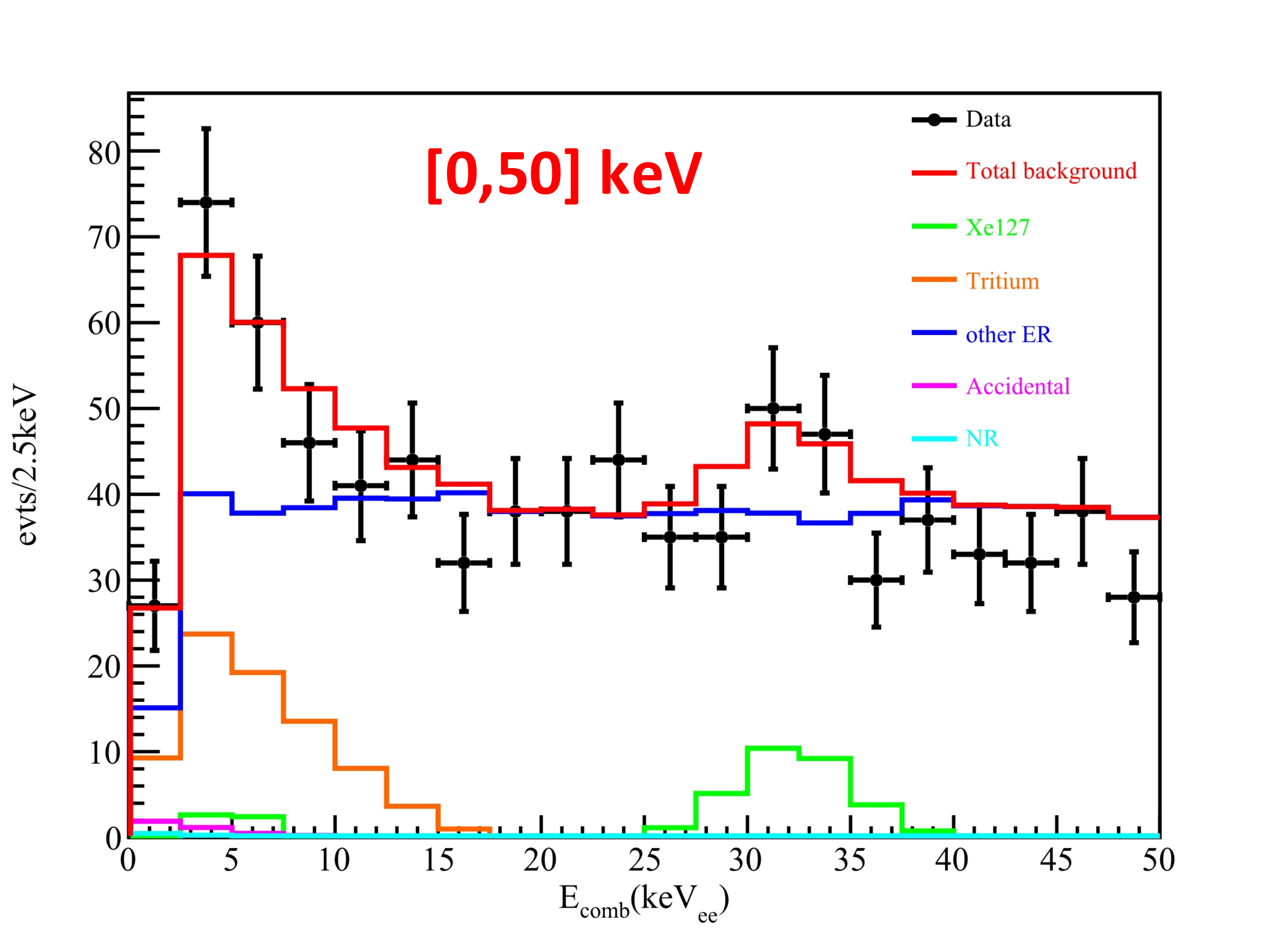
Based on best fit to data (later)

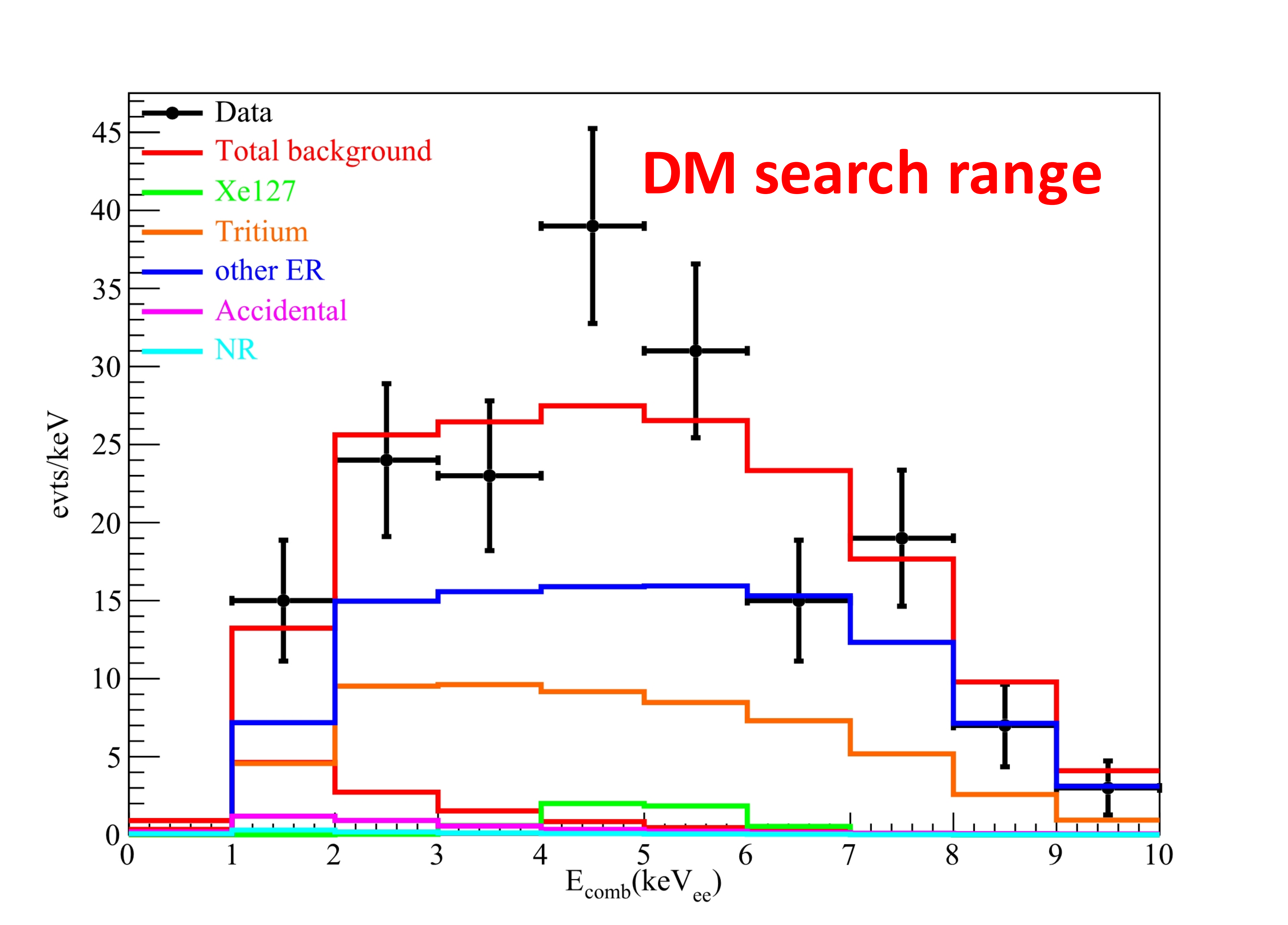
Rest are consistent between Run9 and Run10

0.8 mDRU ~ 2 events a day!

PANDA X

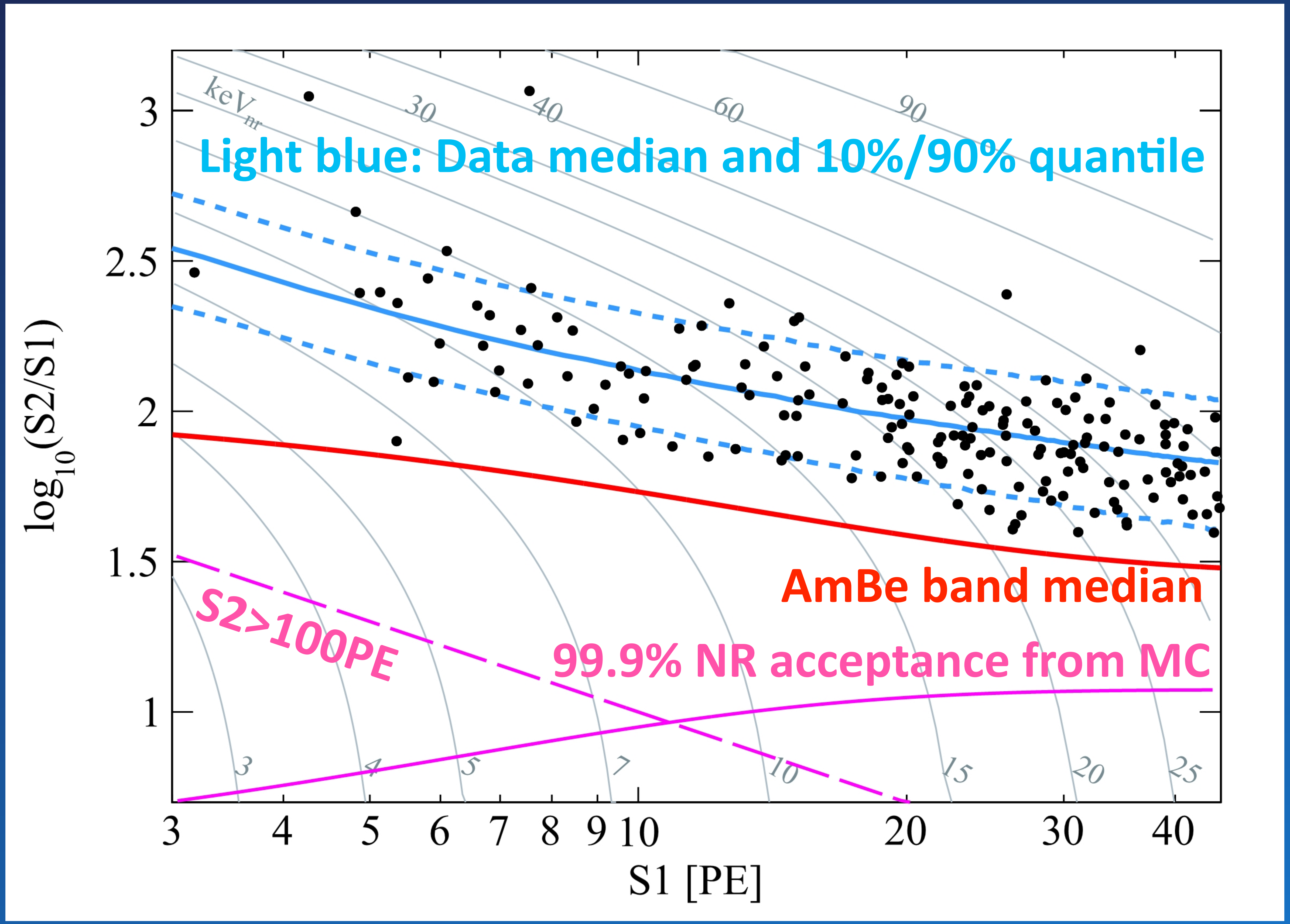
BKG: Energy spectrum in Run 10





Data and expected background in good agreement

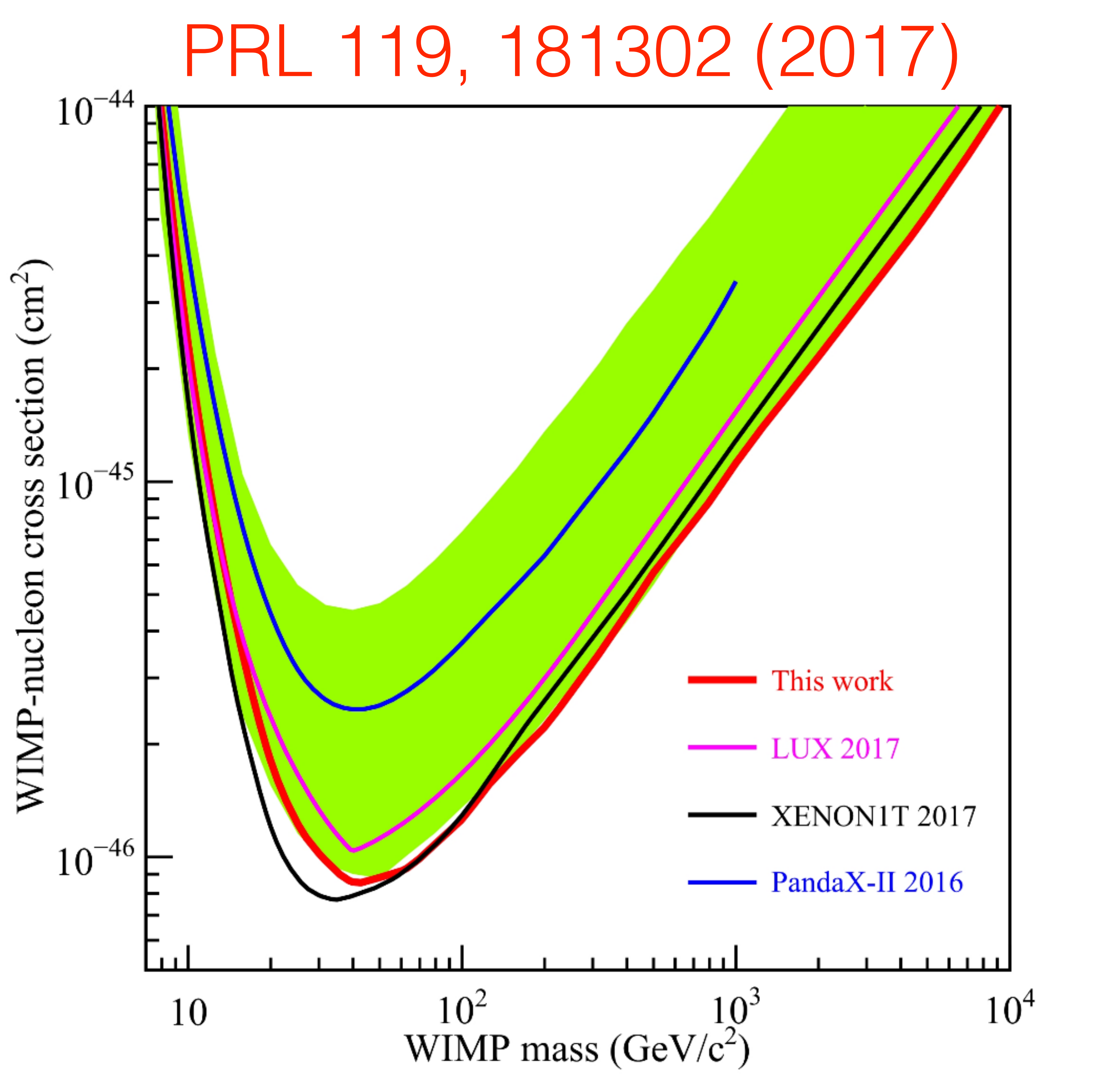
BKG: Distribution of events (run10)

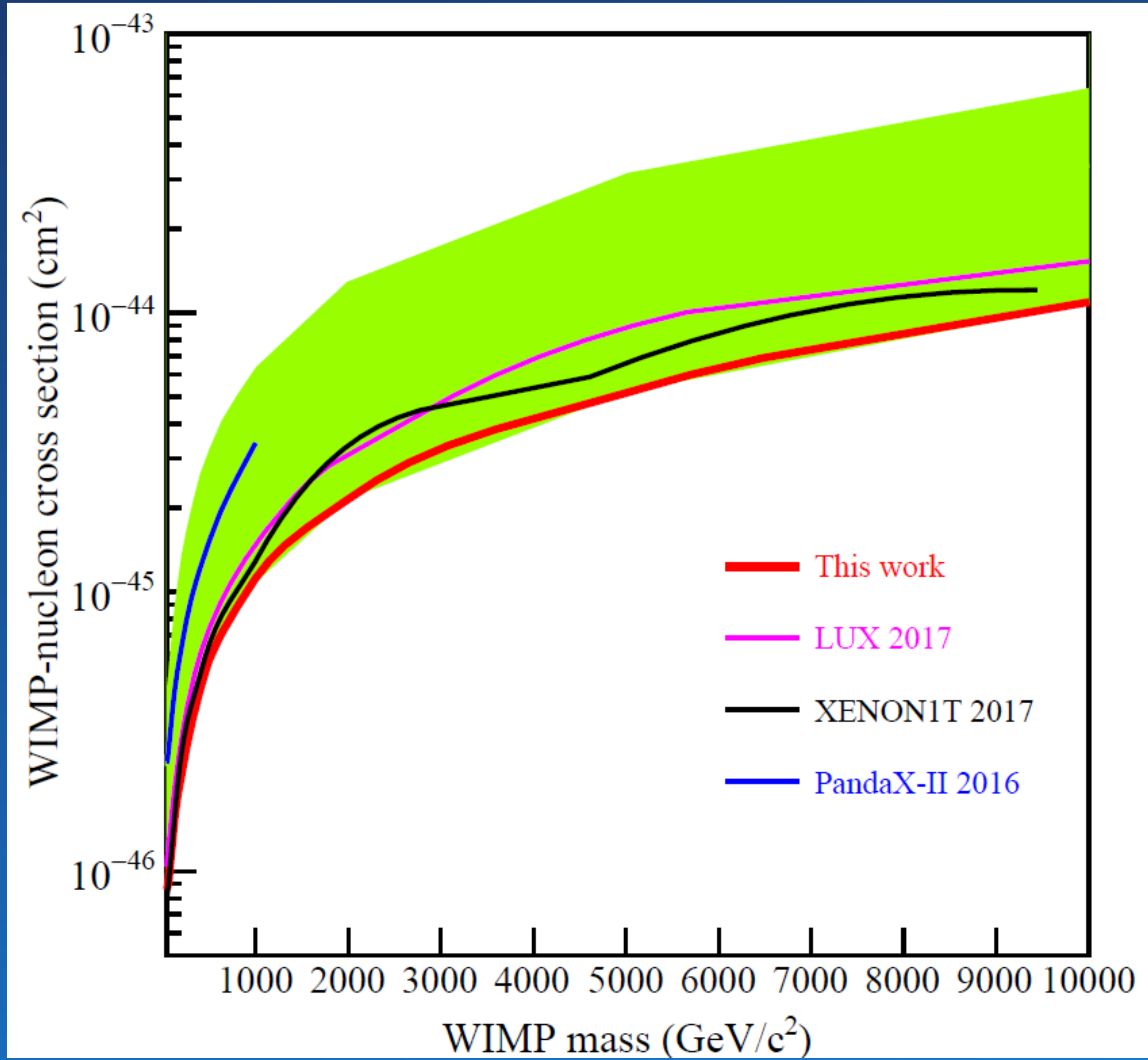


	ER	Accidental	Neutron	Total Fitted	Total Observed
Run9	376.1	13.5	0.85	390±50	389
Below NR Median	2.0	0.9	0.35	3.2±0.9	1
Run10	172.2	3.9	0.83	177±33	**177**
Below NR Median	0.9	0.6	0.33	**1.8±0.5**	**0**

Appears to have a downward fluctuation of background!

WIMP-nucleon SI result



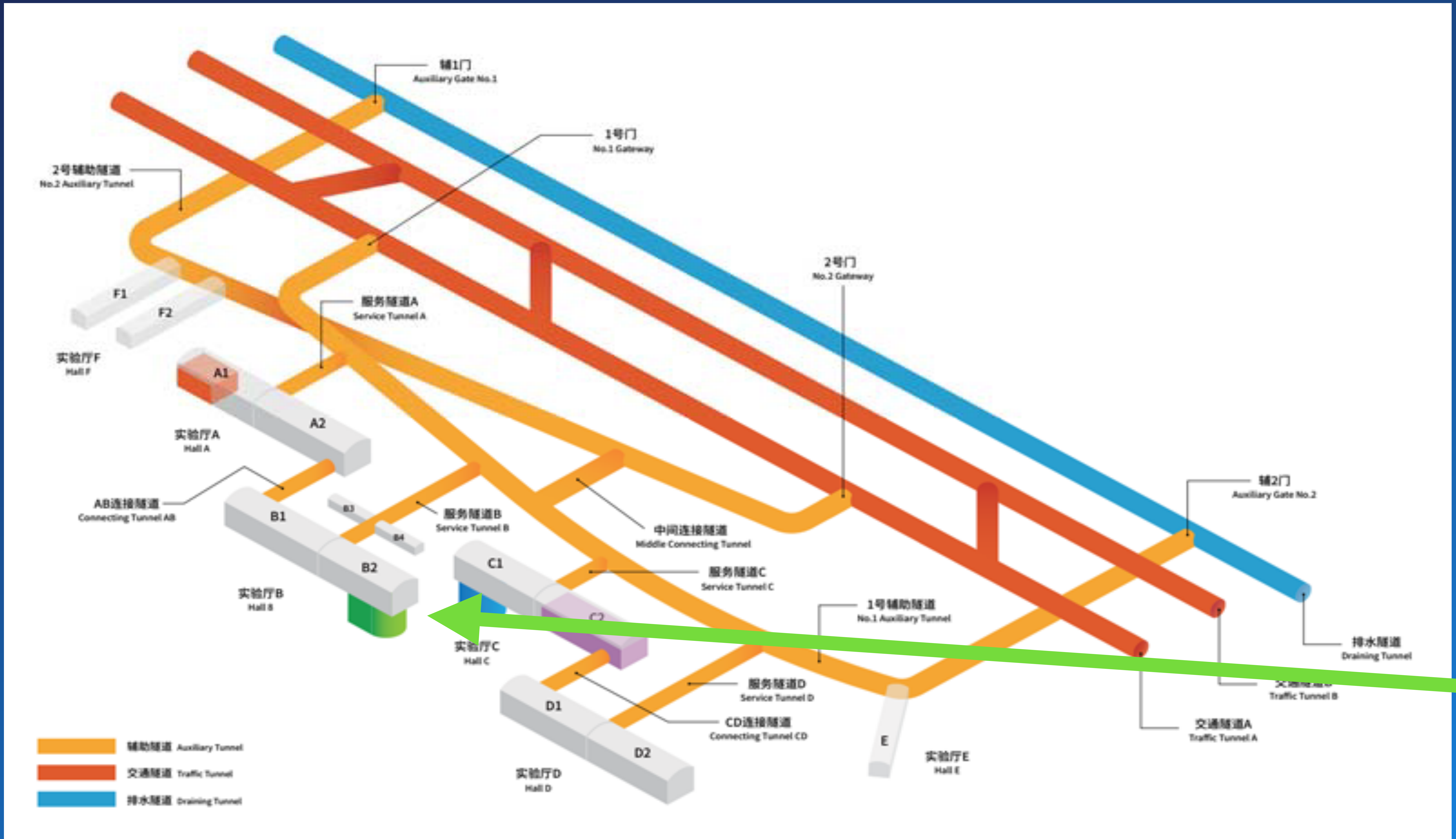


- most stringent limit for WIMP-nucleon cross section for mass >100GeV
- Improved from PandaX-II 2016 limit about 2.5 time for mass>30 GeV
- Lowest exclusion at $8.6\times10^{-47}cm^2$ at $40GeV/c^2$

PandaX

PandaX Future

PandaX new home: CJPL-II

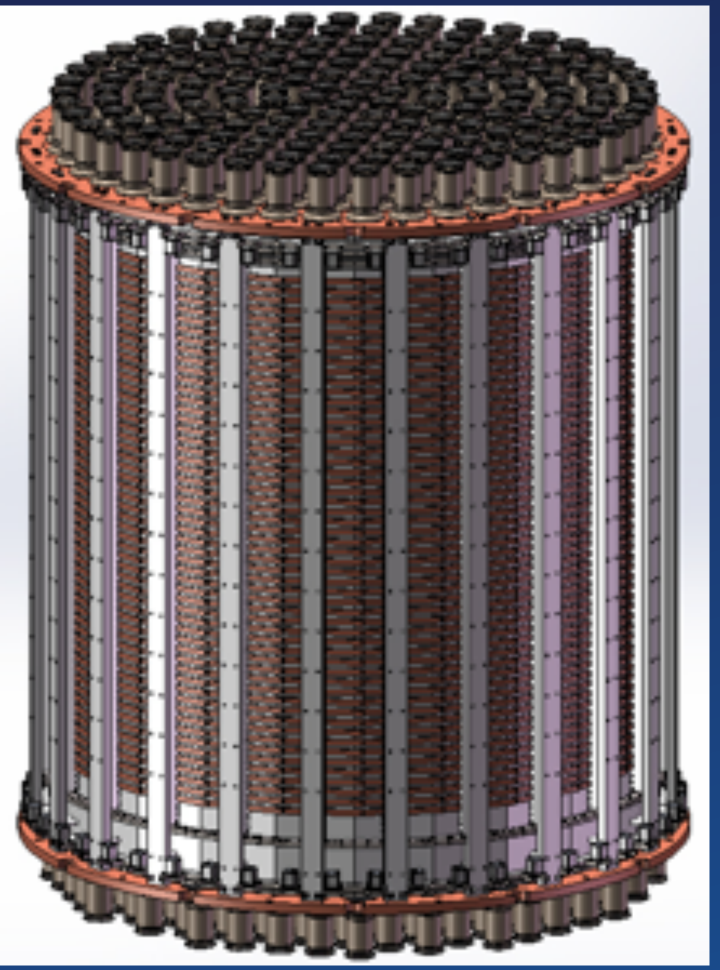


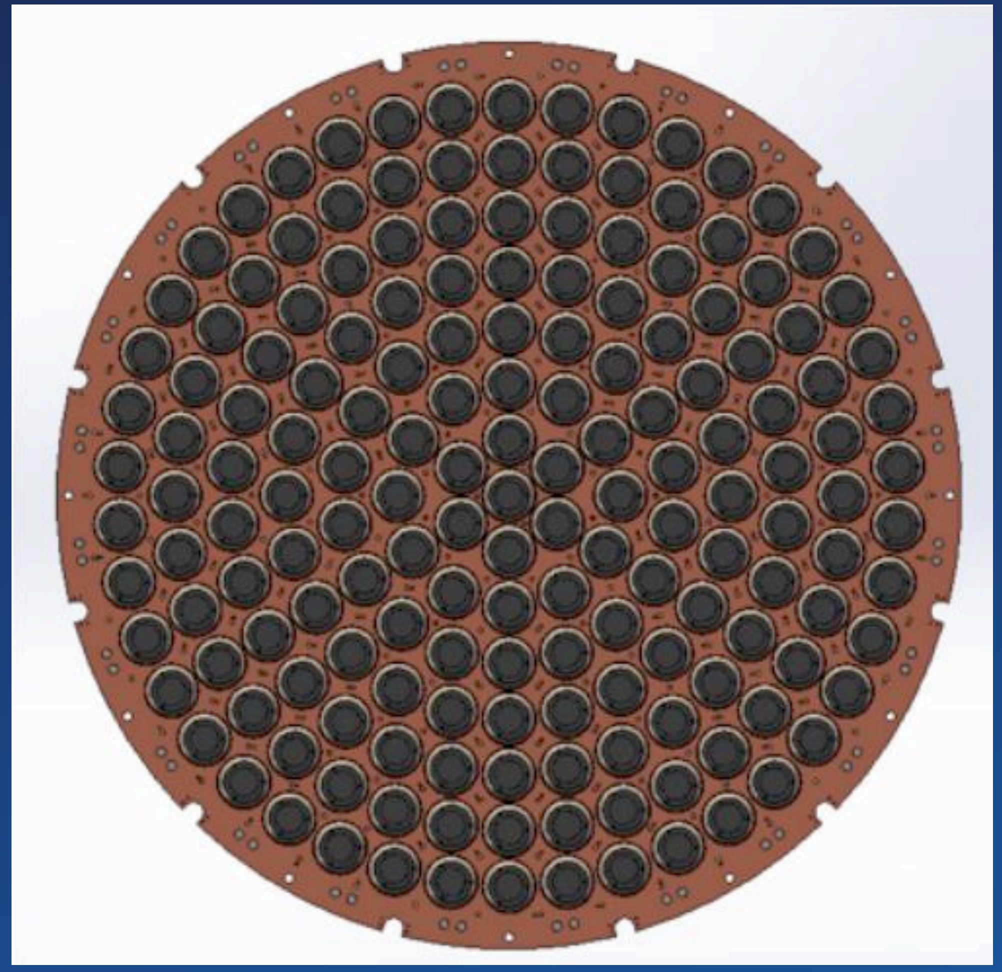
- 8 Experimental Halls
- 14(H)×14(W)×65(L) m each
- Dark matter, 0vDBD, nuclear astrophysics, low background CFT

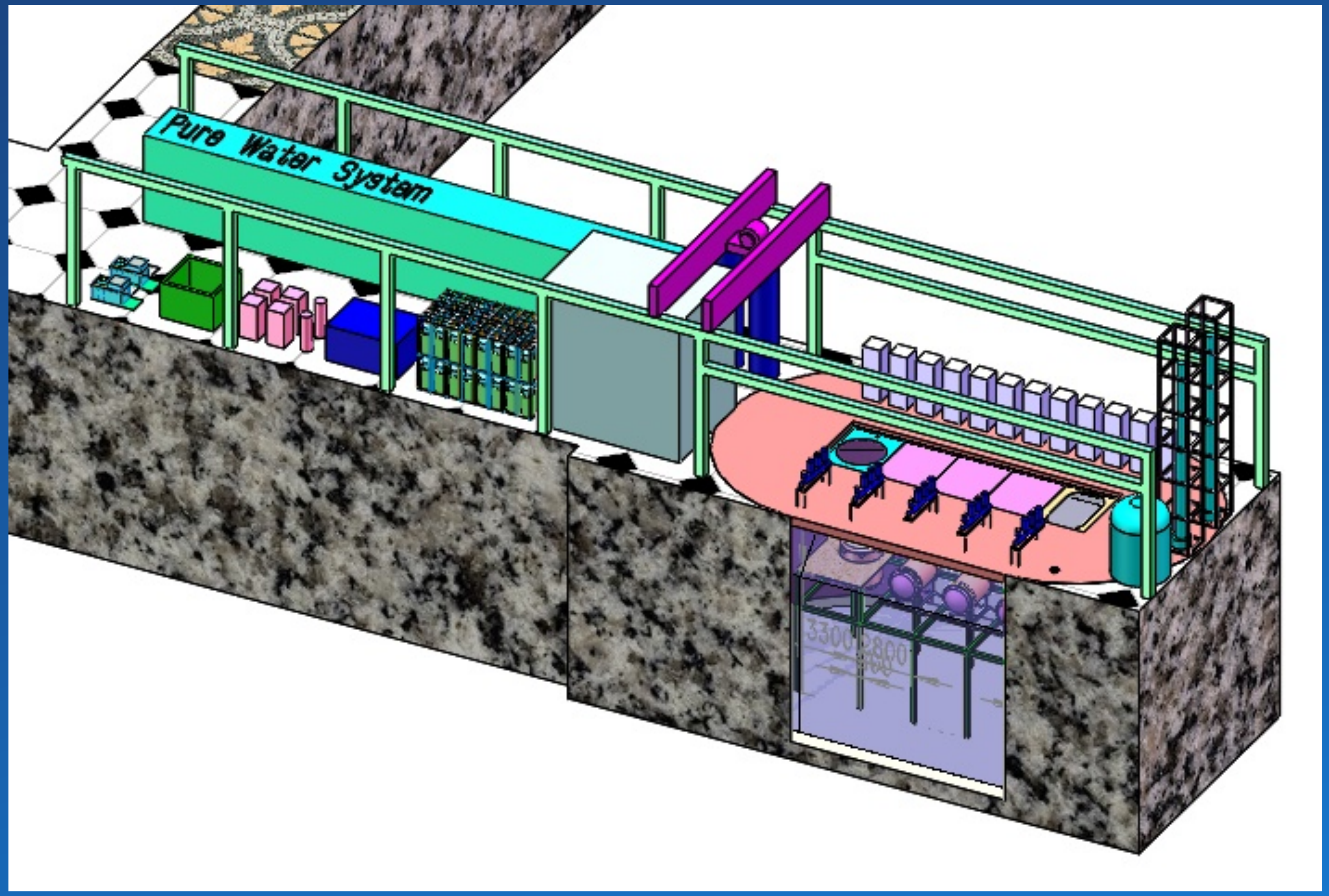
B2, PandaX site!

PANDA X

PandaX-xT Experiment





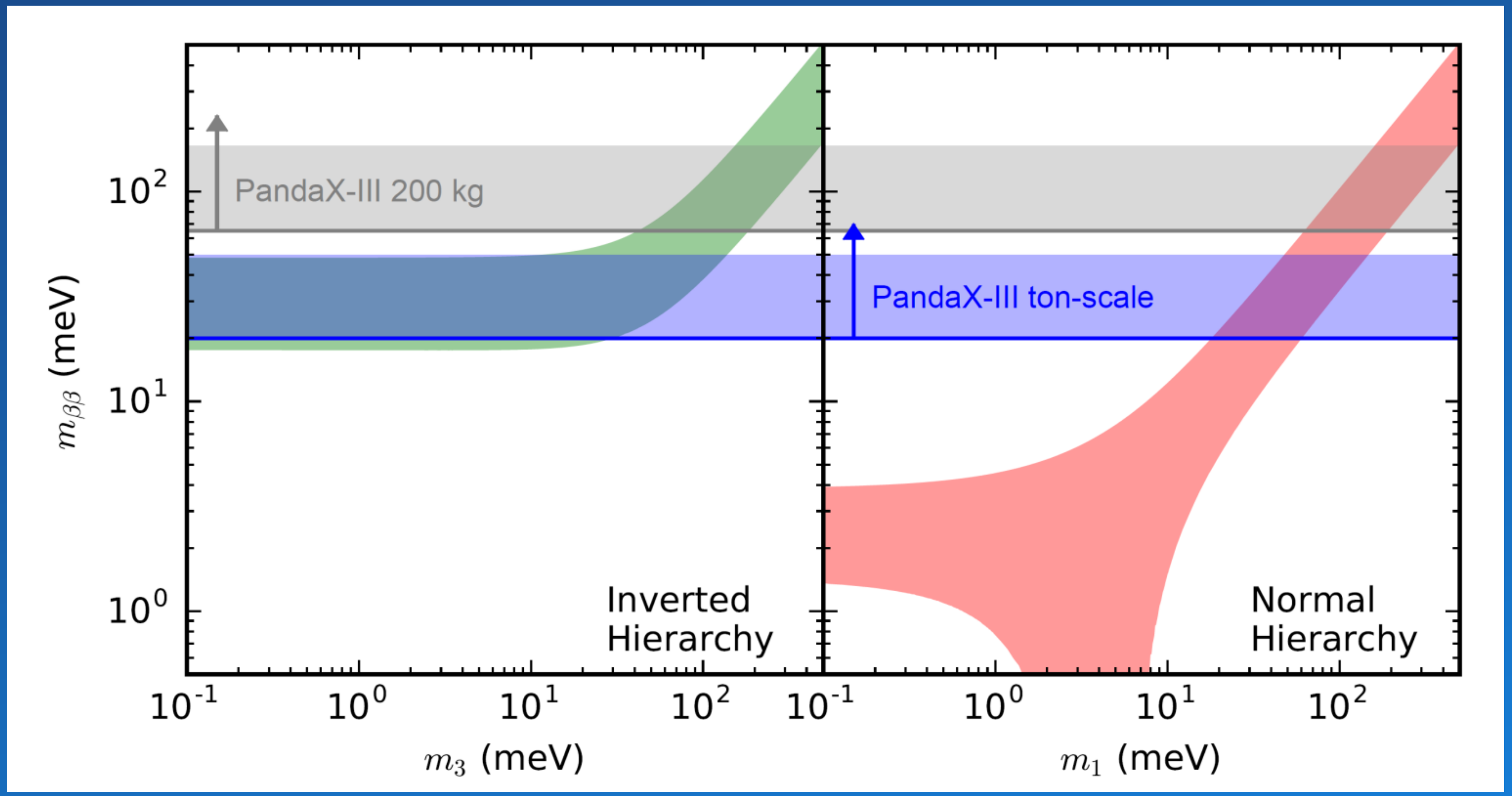


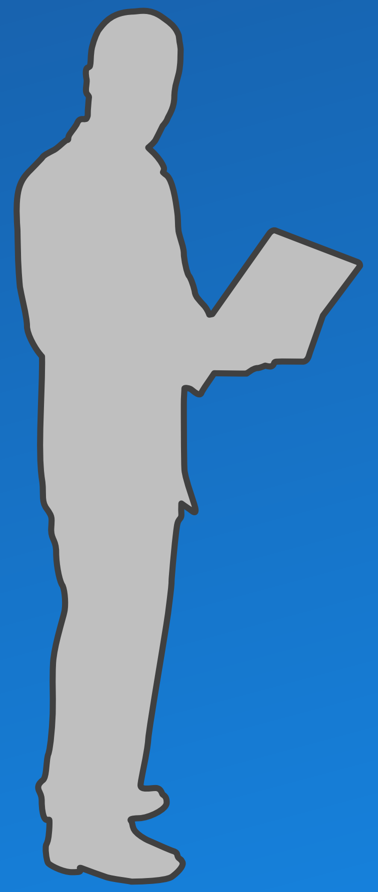
- Preparing new experiments in CJPL-II, hall #B2
- Intermediate stage:
- PandaX-4T (4-ton target) with SI sensitivity $\sim 10^{-47}$ cm^2
- On-site assembly and commissioning: 2019-2020
- Eventual goal: G3 xenon dark matter detector (~30T) in CJPL to "neutrino floor" sensitivity

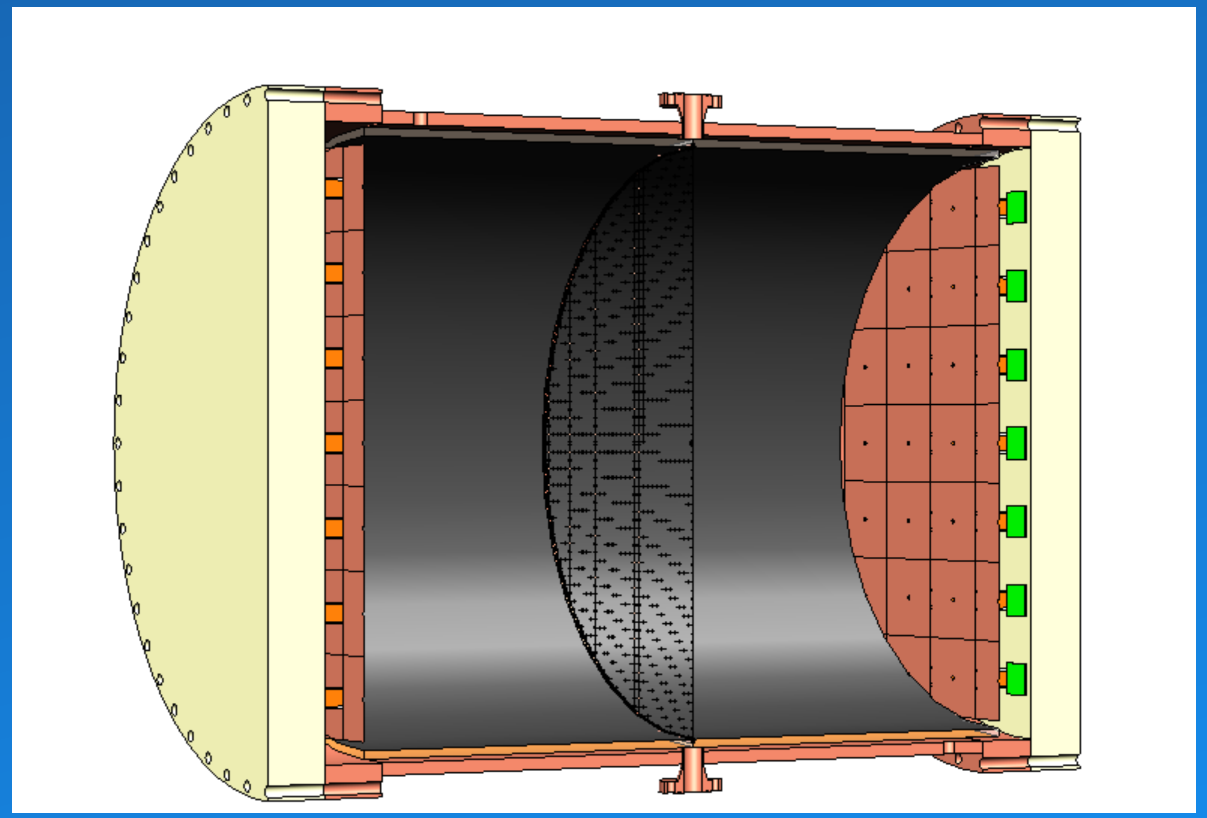
PANDA X

PandaX-III: High pressure ^{136}Xe TPC

- 0DBD signal: two electrons emitting from the same vertex with a summed energy at the Q value (tracking essential)
- TPC: 200 kg, 10 atm, symmetric, double-ended charge readout plane with micromegas module with cathode in the middle
- Four more upgraded modules for a ton scale experiment
- Published CDR recently: ArXiv:1610.08883







Conclusion

- Searching for WIMPs is far from over
- PandaX experiment since 2012 has been gone through two generations of detectors
- PandaX-II has reached and remains at the forefront of the DM search, and will continue data taking till end of 2018
- The collaboration is going forward in preparation for PandaX-III and PandaX-xT.